Motion Control

NI 7350 User Manual

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All Class A products display a simple warning statement of one paragraph in length regarding interference and undesired operation. The FCC rules have restrictions regarding the locations where FCC Class A products can be operated.

Consult the FCC Web site at `www.fcc.gov` for more information.

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This equipment generates and uses radio frequency energy and, if not installed and used in strict accordance with the instructions in this manual and the CE marking Declaration of Conformity*, may cause interference to radio and television reception. Classification requirements are the same for the Federal Communications Commission (FCC) and the Canadian Department of Communications (DOC).

Changes or modifications not expressly approved by NI could void the user's authority to operate the equipment under the FCC Rules.

Class A

Federal Communications Commission

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user is required to correct the interference at their own expense.

Canadian Department of Communications

This Class A digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

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* The CE marking Declaration of Conformity contains important supplementary information and instructions for the user or installer.

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About This Manual

This manual describes the electrical and mechanical aspects of the National Instruments PXI/PCI-7350 motion controller and contains information concerning its installation and operation.

The NI 7350 controller is designed for PXI, CompactPCI, and PCI bus computers.

Conventions

This manual uses the following conventions:

<> — Angle brackets that contain numbers separated by an ellipsis represent a range of values associated with a bit or signal name—for example, AO <3..0>.

» — The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.

♦ — The ♦ symbol indicates that the following text applies only to a specific product, a specific operating system, or a specific software version.

This icon denotes a tip, which alerts you to advisory information.

This icon denotes a note, which alerts you to important information.

This icon denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash. When this symbol is marked on a product, refer to the *Safety Information* section of Chapter 2, *Configuration and Installation*, for information about precautions to take.

bold — Bold text denotes items that you must select or click in the software, such as menu items and dialog box options. Bold text also denotes parameter names.

italic — Italic text denotes variables, emphasis, a cross-reference, or an introduction to a key concept. Italic text also denotes text that is a placeholder for a word or value that you must supply.

`monospace`	Text in this font denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames, and extensions.

Related Documentation

The following documents contain information you might find helpful as you read this manual:

- *NI-Motion Function Help*
- *NI-Motion VI Help*
- *NI-Motion User Manual*
- *Getting Started with NI-Motion for NI 73xx Motion Controllers*
- *PXI Specification*, Revision 2.1
- *PCI Local Bus Specification*, Revision 2.2
- The technical reference manual for the computer you are using

1

Introduction

This chapter includes information about the features of the National Instruments PXI/PCI-7350 controller and information about operating the device.

About the NI 7350 Controller

The NI 7350 controller features advanced motion control with easy-to-use software tools and add-on motion VI libraries for use with LabVIEW.

Features

The NI 7350 controller is a combination servo and stepper motor controller for PXI, CompactPCI, and PCI bus computers. It provides fully-programmable motion control for up to eight independent axes of motion. Coordinated motion is supported through multi-dimensional coordinate spaces. Each axis provides dedicated motion I/O for limit and home switches and additional I/O for general-purpose functions.

You can use the NI 7350 controller for point-to-point and straight-line vector moves. The NI 7350 also performs arbitrary and complex motion trajectories through circular interpolation and contouring.

Servo axes can control DC brushed or brushless servo motors, servo hydraulics, servo valves, and other servo devices, such as closed-loop piezo motor systems. Servo axes always operate in closed-loop mode. These axes use quadrature encoders or analog inputs for position and velocity feedback and provide analog command outputs with an industry-standard range of ±10 V.

Stepper axes control stepper motors in either open or closed-loop mode. They use quadrature encoders or analog inputs for position feedback (closed-loop only), and provide step/direction or clockwise (CW) /counterclockwise (CCW) digital command outputs. All stepper axes support full, half, and microstepping applications.

Hardware

The NI 7350 controller is a high performance controller that uses an advanced dual-processor for embedded real-time control. This powerful functionality provides high-speed communications while off-loading complex motion functions from the host PC for maximum command throughput and system performance.

The NI 7350 features motion profiles that are controlled with enhanced *PID control loop*/*PIVff control loop* high-speed servo update rates. The update rate depends on the number of axes enabled. Refer to Appendix A, *Specifications*, for more information.

Each axis has motion I/O for end-of-travel limit and home switch inputs, breakpoint (position compare) output, trigger (position capture) input, hall effect sensor input, and encoder feedback. The NI 7350 controller also has non-dedicated user I/O including 64 bits of digital I/O and eight analog inputs for ±10 V signals, joystick inputs, or analog sensor monitoring. Additionally, the NI 7350 analog inputs can provide feedback for loop closure.

RTSI

The NI 7350 controller supports the National Instruments Real-Time System Integration (RTSI) bus. The RTSI bus provides high-speed connectivity between National Instruments products, including image acquisition and data acquisition products. Using the RTSI bus, you can easily synchronize several functions to a common trigger (position capture) or timing event across multiple motion, image, or data acquisition devices.

What You Need to Get Started

To set up and use the NI 7350 controller, you must have the following items:

- ❑ NI PXI-7350 controller or NI PCI-7350 controller and documentation
- ❑ NI-Motion driver software and documentation

- ❑ One of the following software packages and documentation:
  - LabVIEW
  - LabWindows™/CVI™
  - Measurement Studio
  - C/C++
  - Microsoft Visual Basic
- ❑ A computer with an available PXI, CompactPCI, or PCI slot

Software Programming Choices

The NI 7350 controller comes with a simple but powerful high-level application programming interface (API) that makes it easy to program. You can execute all setup and motion control functions by calling into a dynamically-linked library (DLL). You can use the full function set implementations for LabVIEW and LabWindows/CVI, or call the NI-Motion libraries from C and Visual Basic.

National Instruments Application Software

LabVIEW is based on the graphical programming language, G, and features interactive graphics and a state-of-the-art user interface. In LabVIEW, you can create 32-bit compiled programs and stand-alone executables for custom automation, data acquisition, test, measurement, and control solutions. National Instruments offers the NI-Motion VI Library, which is a series of virtual instruments (VIs) for using LabVIEW with National Instruments motion control hardware. The NI-Motion VI library implements the full API, along with a useful set of example programs.

ANSI C-based LabWindows/CVI also features interactive graphics and a state-of-the-art user interface. Using LabWindows/CVI, you can generate C code for custom data acquisition, test, measurement, and automation solutions. The NI-Motion software includes a series of example programs for using LabWindows/CVI with National Instruments motion control hardware.

NI Motion Assistant offers a point-and-click interface for creating motion control sequences quickly and easily. When you have created a motion task, you can use Motion Assistant to output the task in LabVIEW code or code recipes.

Optional Equipment

National Instruments offers a variety of products for use with the NI 7350 controller, including the following accessories:

- Cables and cable assemblies for motion and digital I/O
- Universal Motion Interface (UMI) wiring connectivity blocks with integrated motion signal conditioning and motion inhibit functionality
- Stepper and servo motor compatible drive amplifier units with integrated power supply and wiring connectivity
- Connector blocks and shielded and unshielded 68-pin screw terminal wiring aids
- RTSI bus cables for connection with other NI devices

For more specific information about these products, refer to the National Instruments catalog, the National Instruments Web site at `ni.com`, or call your National Instruments sales representative.

Motion I/O Connections

The external motion and digital I/O connectors on the NI 7350 controller are high-density, 68-pin female VHDCI connectors.

For custom cables, use the AMP mating connector (part number 787801-01).

2

Configuration and Installation

This chapter describes how to configure and install the National Instruments PXI/PCI-7350 controller.

Software Installation

Before installing the NI 7350 controller, install the NI-Motion software and, if appropriate, the NI-Motion VI libraries. For specific installation instructions, refer to *Getting Started with NI-Motion for NI 73xx Motion Controllers*, which is installed in the `NI-Motion/Documentation` folder where you installed NI-Motion. The default directory is `Program Files\National Instruments\NI-Motion`.

Note If you do not install the NI-Motion driver software before attempting to use the NI 7350, the system will not recognize the NI 7350 and you will be unable to configure or use the controller.

Controller Configuration

Because the motion I/O-related configuration of NI 7350 controller is performed entirely with software, it is not necessary to set jumpers for motion I/O configuration.

The PXI-7350 and PCI-7350 controllers are fully compatible with the industry standard *PXI Specification*, Revision 2.1 and the *PCI Local Bus Specification*, Revision 2.2, respectively. This compatibility allows you to configure the computer to automatically perform all bus-related configuration without user interaction. It is not necessary to configure jumpers for bus-related configuration.

Note When adding or removing a controller from a Windows 2000/XP system, you must be logged on with administrator-level access. After you have restarted the system, you may need to refresh Measurement & Automation Explorer (MAX) to view the new controller.

Safety Information

Caution The following section contains important safety information that you *must* follow when installing and using the NI 7350.

Do *not* operate the device in a manner not specified in this document. Misuse of the device can result in a hazard. You can compromise the safety protection built into the device if the device is damaged in any way. If the device is damaged, return it to National Instruments (NI) for repair.

Do *not* substitute parts or modify the device except as described in this document. Use the device only with the chassis, modules, accessories, and cables specified in the installation instructions. You *must* have all covers and filler panels installed during operation of the device.

Do *not* operate the device in an explosive atmosphere or where there may be flammable gases or fumes. If you must operate the device in such an environment, it must be in a suitably rated enclosure.

If you need to clean the device, use a soft, nonmetallic brush. Make sure that the device is completely dry and free from contaminants before returning it to service.

Operate the device only at or below Pollution Degree 2. Pollution is foreign matter in a solid, liquid, or gaseous state that can reduce dielectric strength or surface resistivity. The following is a description of pollution degrees:

- Pollution Degree 1 means no pollution or only dry, nonconductive pollution occurs. The pollution has no influence.
- Pollution Degree 2 means that only nonconductive pollution occurs in most cases. Occasionally, however, a temporary conductivity caused by condensation must be expected.
- Pollution Degree 3 means that conductive pollution occurs, or dry, nonconductive pollution occurs that becomes conductive due to condensation.

Note The NI 7350 is intended for indoor use only.

You *must* insulate signal connections for the maximum voltage for which the device is rated. Do *not* exceed the maximum ratings for the device. Do *not* install wiring while the device is live with electrical signals. Do not remove or add connector blocks when power is connected to the system.

Remove power from signal lines before connecting them to or disconnecting them from the device.

Operate the device at or below the *measurement category*[1] marked on the hardware label. Measurement circuits are subjected to *working voltages*[2] and transient stresses (overvoltage) from the circuit to which they are connected during measurement or test. Measurement categories establish standard impulse withstand voltage levels that commonly occur in electrical distribution systems. The following is a description of measurement categories:

- Measurement Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS[3] voltage. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.
- Measurement Category II is for measurements performed on circuits directly connected to the electrical distribution system. This category refers to local-level electrical distribution, such as that provided by a standard wall outlet (for example, 115 AC voltage for U.S. or 230 AC voltage for Europe). Examples of Installation Category II are measurements performed on household appliances, portable tools, and similar devices/modules.
- Measurement Category III is for measurements performed in the building installation at the distribution level. This category refers to measurements on hard-wired equipment such as equipment in fixed installations, distribution boards, and circuit breakers. Other examples are wiring, including cables, bus bars, junction boxes, switches, socket outlets in the fixed installation, and stationary motors with permanent connections to fixed installations.
- Measurement Category IV is for measurements performed at the primary electrical supply installation (<1,000 V). Examples include electricity meters and measurements on primary overcurrent protection devices and on ripple control units.

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[1] Measurement categories, also referred to as *installation categories*, are defined in electrical safety standard IEC 61010-1.

[2] Working voltage is the highest rms value of an AC or DC voltage that can occur across any particular insulation.

[3] MAINS is defined as a hazardous live electrical supply system that powers equipment. Suitably rated measuring circuits may be connected to the MAINS for measuring purposes.

Hardware Installation

You can install the NI 7350 controller in any open compatible expansion slot in the computer. Appendix A, *Specifications*, lists the maximum power required for the NI 7350 controller.

The following instructions are for general installation. Refer to the computer user manual or technical reference manual for specific instructions and warnings.

Caution The NI 7350 controller is a sensitive electronic device shipped in an antistatic bag. Open only at an approved workstation and observe precautions for handling electrostatic-sensitive devices.

- PXI-7350

1. Power off and unplug the chassis.

Caution To protect yourself and the chassis from electrical hazards, the computer should remain unplugged until the installation is complete.

2. Choose an unused +3.3 V or +5 V peripheral slot and remove the filler panel.
3. Touch a metal part on the chassis to discharge any static electricity that might be on your clothes or body. Static electricity can damage the controller.
4. Insert the PXI controller into the chosen slot. Use the injector/ejector handle to fully insert the device into place.
5. Screw the front panel of the PXI controller to the front panel mounting rails of the chassis.
6. Visually verify the installation.

Caution Make sure you have correctly connected all safety devices before you power on the motion system. Safety devices include inhibits, limit switches, and emergency shut down circuits.

Caution Always power on the chassis containing the NI 7350 controller then initialize the controller before you power on the rest of the motion system. Power off in the reverse order.

7. Plug in and power on the chassis.
8. Initialize the controller.

- PCI-7350

1. Power off and unplug the computer.

Caution To protect yourself and the computer from electrical hazards, the computer should remain unplugged until the installation is complete.

2. Open the computer case to expose access to the PCI expansion slots.
3. Choose an unused +3.3 V or +5 V PCI slot, and remove the corresponding expansion slot cover on the back panel of the computer.
4. Touch a metal part on the computer case to discharge any static electricity that might be on your clothes or body before handling the controller. Static electricity can damage the controller.
5. Gently rock the controller into the slot. The connection may be tight, but do *not* force the controller into place.
6. If required, screw the mounting bracket of the controller to the back panel rail of the computer.
7. Replace the cover.

Caution Make sure you have correctly connected all safety devices before you power on the motion system. Safety devices include inhibits, limit switches, and emergency shut down circuits.

Caution Always power on the computer containing the NI 7350 controller then initialize the controller before you power on the rest of the motion system. Power off in the reverse order.

8. Plug in and power on the computer.
9. Initialize the controller.

Note When adding or removing a controller from a Windows 2000/XP system, you must be logged on with administrator-level access. After you have restarted the system, you may need to refresh MAX to view the new controller.

Connecting Brushless Servo Motors

The NI 7350 controller can connect to brushless servo drives that perform sinusoidal commutation or to drives that do not. When connecting to a drive that performs the sinusoidal commutation, only one DAC output is required per axis. For information about configuring the NI-Motion

software to work with this type of system, refer to the *NI-Motion User Manual*.

When connecting to a drive that does not perform the sinusoidal commutation, the NI 7350 commutates the first two phases and the servo drive determines the third. Therefore, two DAC outputs are required per axis. Refer to the *Measurement & Automation Explorer Help for Motion* for information about configuring the NI-Motion software for brushless servo motors.

Connecting the Hall Effect Sensors

Before the NI 7350 can calculate the commutation values, some form of initialization is necessary to determine the initial commutation phase angle of the brushless motor each time the controller is powered on, reset, or reconfigured.

One method of initialization is to connect Hall effect sensors to detect the commutation phase angle of the motor. You can specify how the system is configured in MAX.

Tip If you do not connect Hall effect sensors, you can set the commutation phase angle directly, or through a process called *shake and wake*. Shake and wake requires moving the motors to the 0º angle and setting the commutation phase angle to match.

It is important to correctly connect the Hall effect sensors to the controller so that the sensors accurately determine the commutation phase angle. Complete the following steps to connect the Hall effect sensors.

1. Locate the Hall effect sensor phase sequence diagram that applies to the motor you are using. The manufacturer of the motor should provide this diagram with the motor documentation.

Note The NI 7350 controller can use Hall effect sensors having three sensor outputs per motor. Each output is 120 degrees out of phase from the previous output.

2. Wire the Hall effect sensors based on the Hall effect sensor phase sequence diagram for the motor and Figures 2-1 and 2-2.

   Match the Hall effect sensor phase sequence diagram for the motor with one of the diagrams in Figures 2-1 and 2-2. The diagrams on the left represent the diagram supplied with the motor. The diagrams on the right represent the expected inputs to the UMI or NI 7350. The arrows in the middle show the correct path to wire the Hall effect sensor outputs into the UMI or NI 7350 inputs.

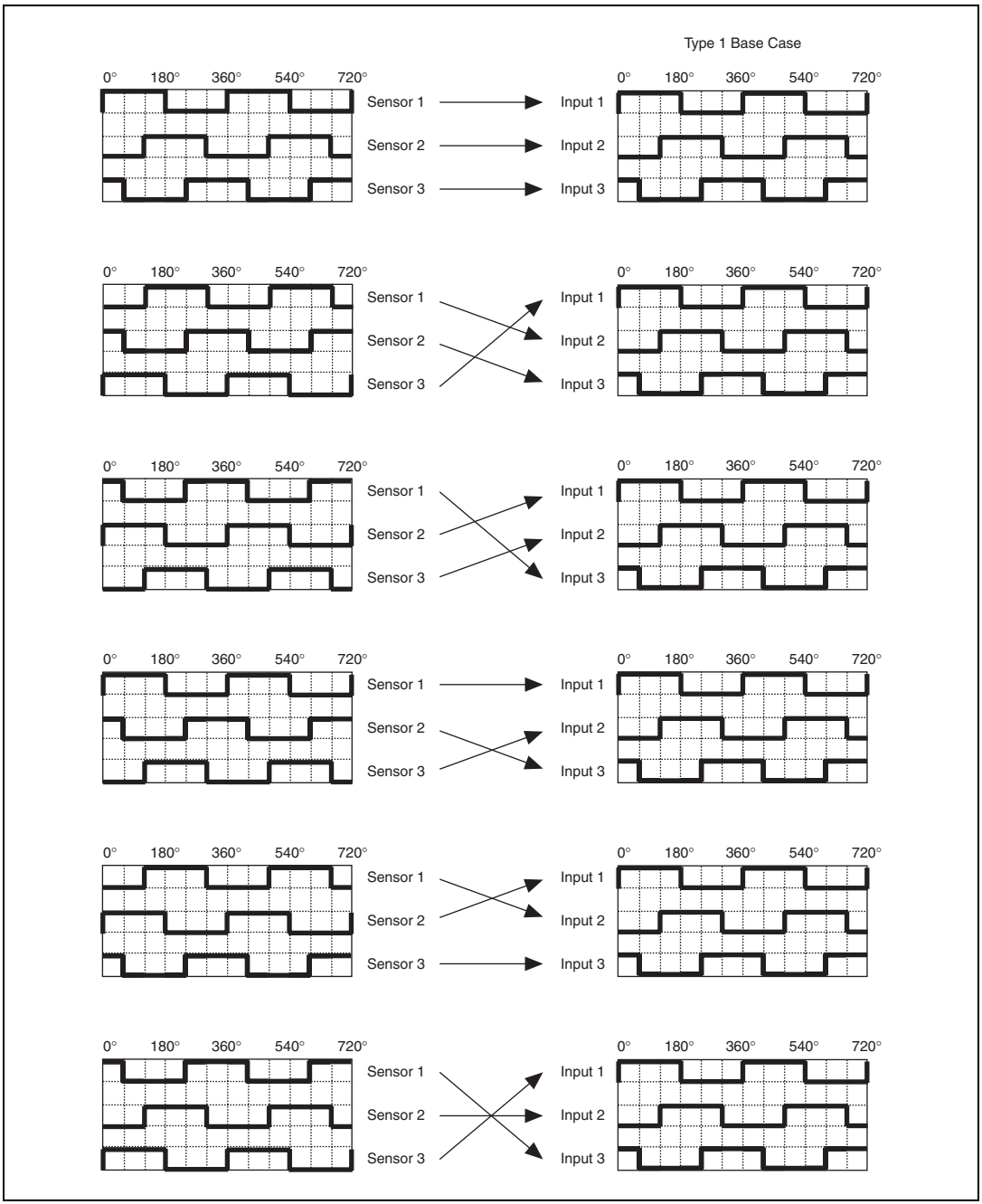


Figure 2-1. Type 1 Hall Sensor Wiring Diagrams

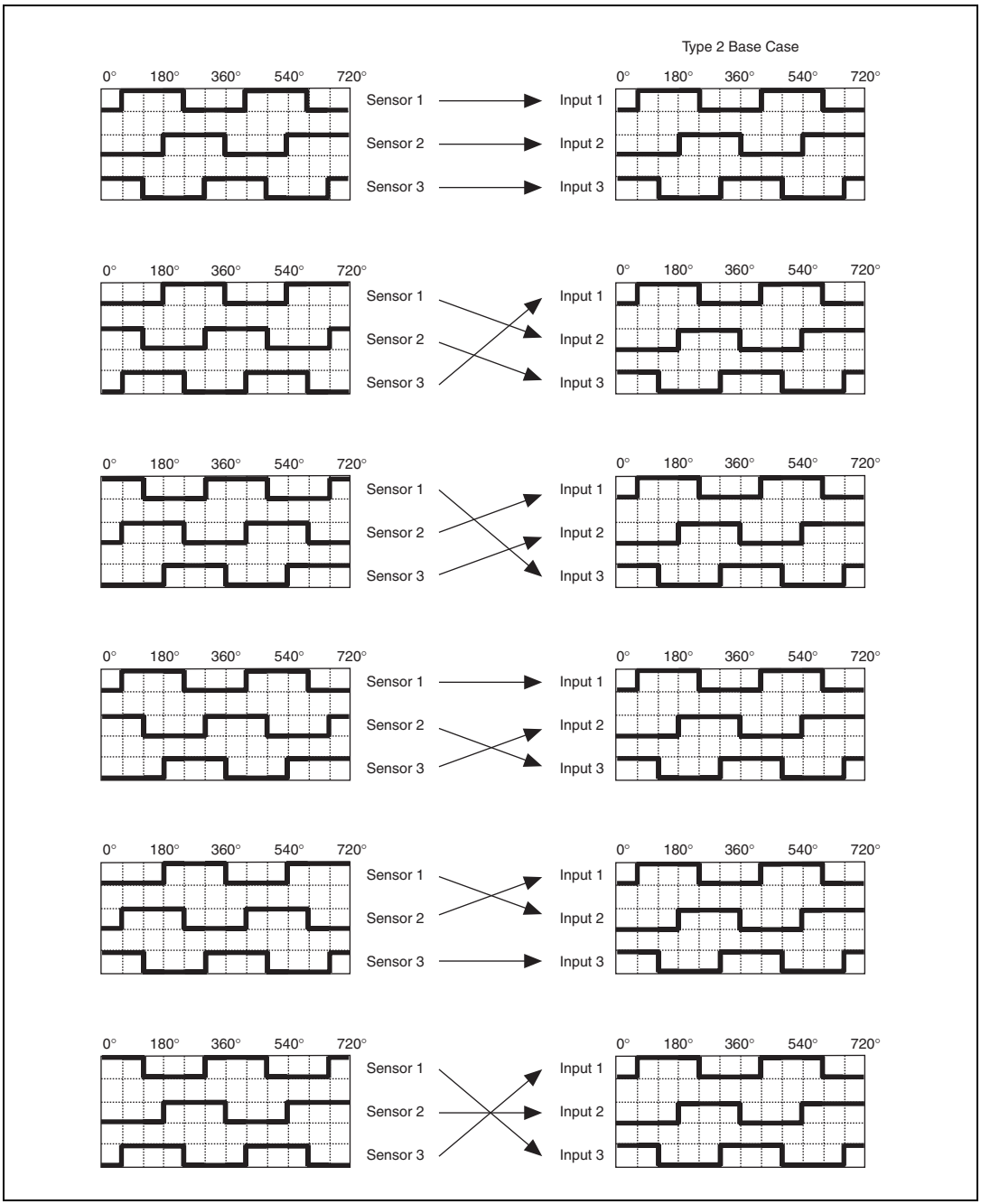


Figure 2-2. Type 2 Hall Sensor Wiring Diagrams

For example, if the diagram supplied with the motor matches the third Type 2 diagram, wire Hall effect sensor 1 to input 3 on the UMI or NI 7350, and then wire sensor 2 to input 1 and wire sensor 3 to input 2.

The Hall effect sensor inputs for Axes 1, 2, 5, and 6 are defined as follows:

- Axis 1 uses digital port 4, bits 2–4, with bit 2 as input 1.
- Axis 2 uses digital port 4, bits 5–7, with bit 5 as input 1.
- Axis 5 uses digital port 8, bits 2–4, with bit 2 as input 1.
- Axis 6 uses digital port 8, bits 5–7, with bit 5 as input 1.

Refer to Figure 5-7, *68-Pin Digital I/O Connector Pin Assignments (Ports 1–4)*, and Figure 5-8, *68-Pin Digital I/O Connector Pin Assignments (Ports 5–8)*, for detailed pinouts of the digital I/O connectors.

3. Configure the system in MAX. There are two base types of Hall effect sensor inputs. Set the NI-Motion software to the base sensor type you are using.

   If the motor documentation matches any of the patterns in Figure 2-1, you are using Type 1, which matches the graph in Figure 2-3.

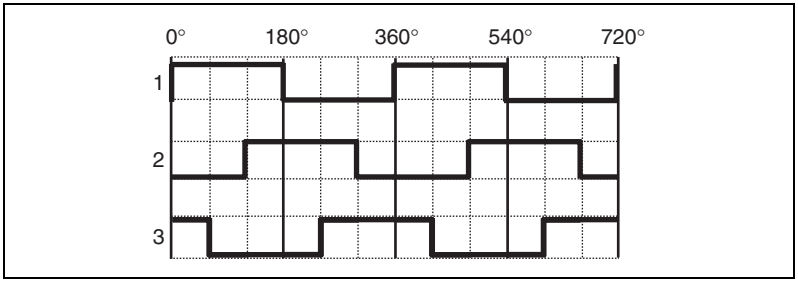


Figure 2-3. Type 1 Hall Sensor Phasing Sequence Diagram

If the motor documentation matches any of the patterns in Figure 2-2, you are using Type 2, which matches the graph in Figure 2-4.

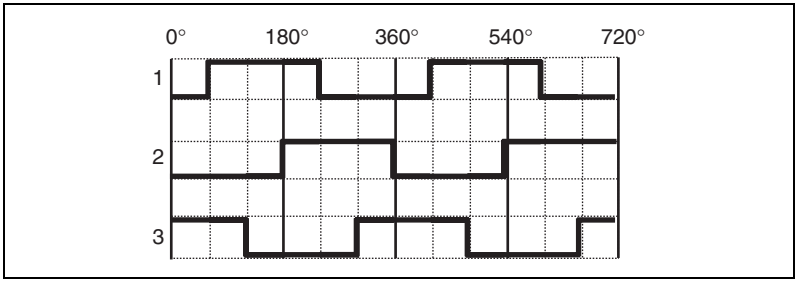


Figure 2-4. Type 2 Hall Sensor Phasing Sequence Diagram

Refer to the *Measurement & Automation Explorer Help for Motion* for information about configuring the NI-Motion software for brushless servo motors.

Connecting the Motor Leads

For the brushless motor to generate maximum torque, the motion system must output the commutation on the three motor phases correctly. Two of the phases are controlled by the NI 7350 controller, and the third phase is generated by the drive.

The primary output of the NI 7350 wires into the primary input of the drive. The secondary output wires into the secondary input of the drive. Use MAX to configure the NI 7350 for onboard sinusoidal commutation. MAX automatically assigns the primary and secondary outputs. Refer to the *Measurement & Automation Explorer Help for Motion* for more information.

When you wire the brushless motor to the drive, use the commutation diagram for the motor as a reference. The manufacturer of the motor typically provides this diagram with the motor documentation.
The commutation diagram shows the expected value on each of the motor leads at each angle in the commutation phase, typically in 60-degree increments. Table 2-1 shows an example of a motor phasing commutation diagram, and Figure 2-5 shows the corresponding graphical representation.

Table 2-1. Motor Phasing Diagram

Motor Lead	0º	60º	120º	180º	240º	300º
A	+	+	NC	–	–	NC
B	–	NC	+	+	NC	–
C	NC	–	–	NC	+	+

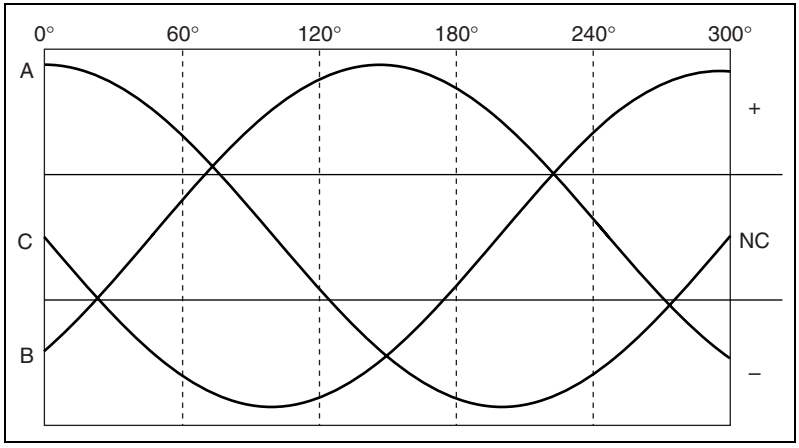


Figure 2-5. Sine Wave Motor Phasing Diagram

Table 2-2 shows the correct method of wiring a brushless motor to the drive.

Table 2-2. Correct Wiring Diagram At 0º Commutation Phase

Drive Motor Output	Brushless Motor Lead State
1	No Current (NC)
2	Positive Current
3	Negative Current

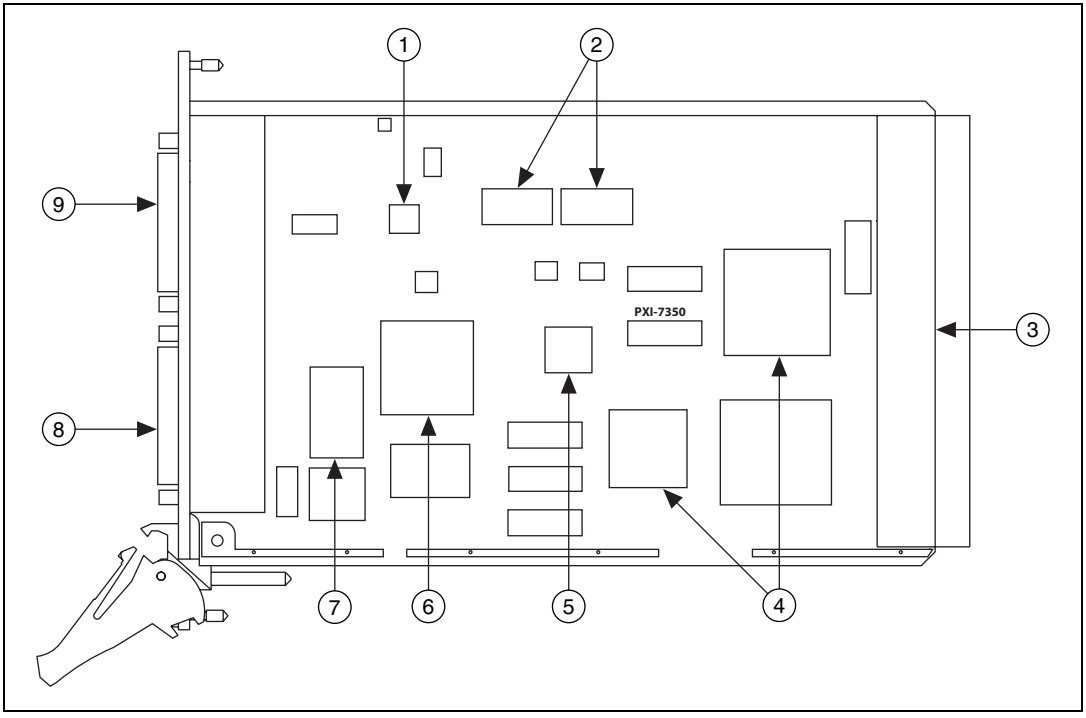
For example, if the motor has the phasing characteristics described in Table 2-1, wire the motor lead C to the motor output 1 on the drive. You wire the lead this way because the motor lead C calls for No Current at 0º Commutation Phase, and drive motor output 1 matches the No Current requirement. Similarly, wire motor lead A to motor output 2 and motor lead B to motor output 3 on the drive.

3

Hardware Overview

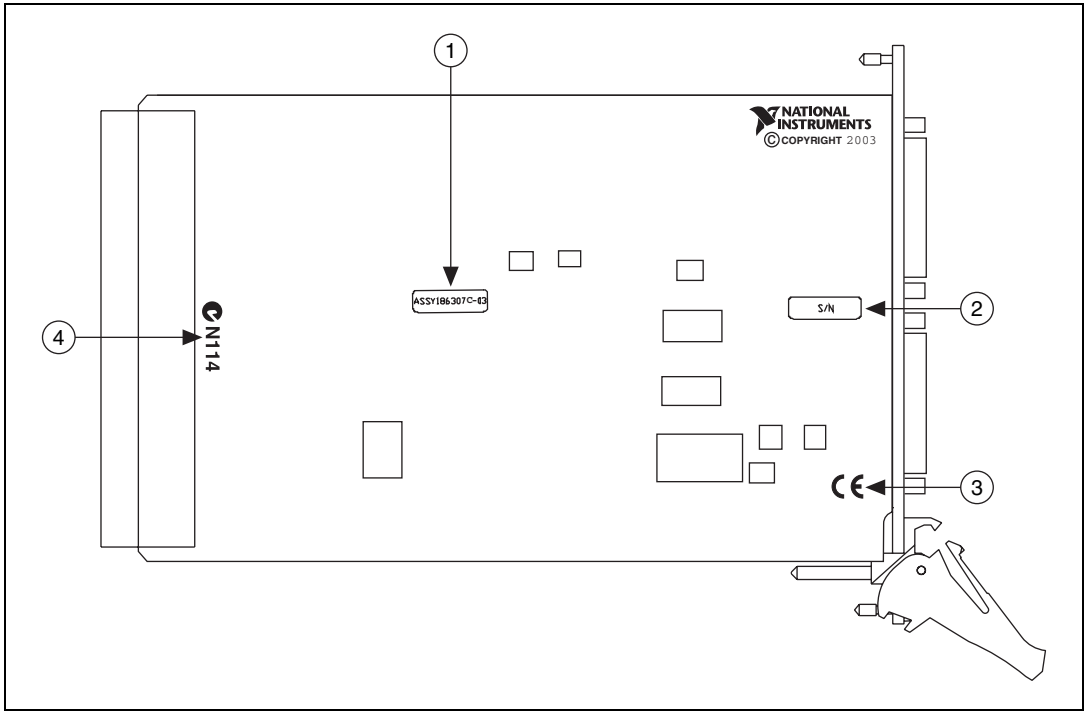
This chapter presents an overview of the National Instruments PXI/PCI-7350 controller hardware functionality.

Figures 3-1 and 3-2 illustrate the functional components of the NI PXI-7350.



1	16-bit ADC	6	32-bit CPU
2	16-bit DACs	7	Nonvolatile FLASH Memory
3	RTSI and PXI Bus Connector	8	68-pin Digital I/O Connectors
4	Field-Programmable Gate Arrays	9	68-pin Motion I/O Connectors
5	DSP		

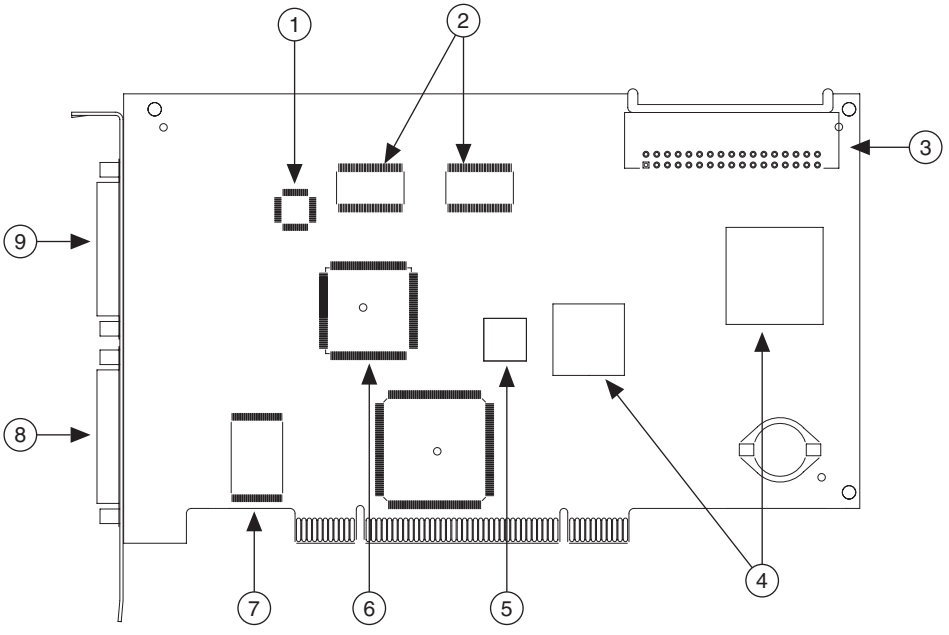
Figure 3-1. PXI-7350 Parts Locator Diagram (Front Panel)



1 Assembly Number Label	3 Symbol Indicating CE Compliance
2 Serial Number Label	4 Identification Number (used in Australia)

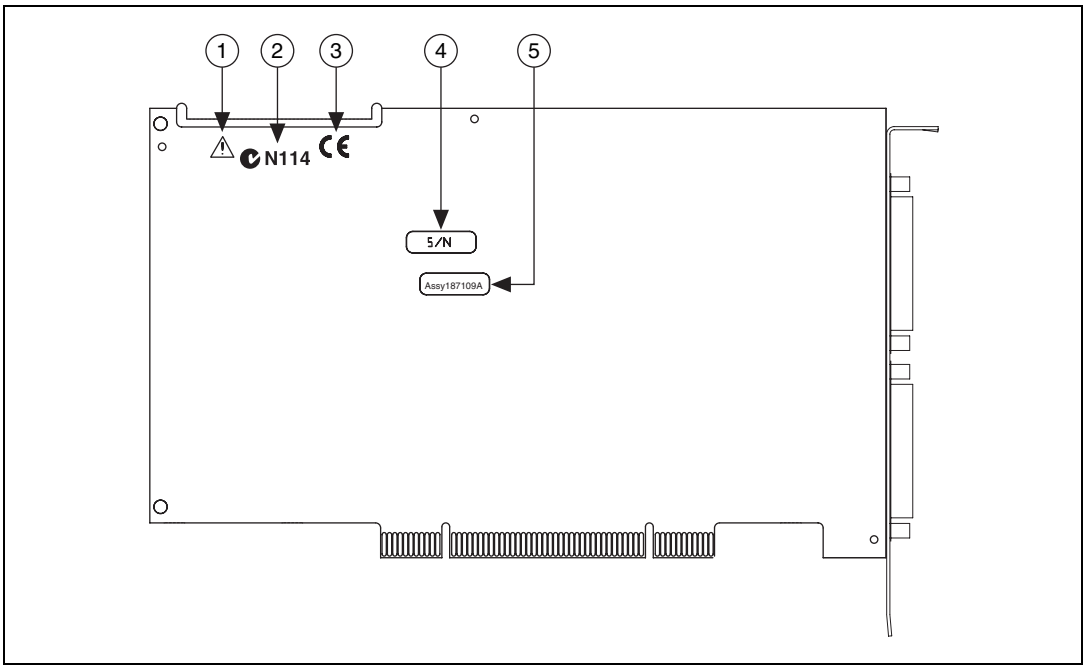
Figure 3-2. PXI-7350 Parts Locator Diagram (Back Panel)

Figures 3-3 and 3-4 show the NI PCI-7350 parts locator diagrams.



1	16-bit ADC	6	32-bit CPU
2	16-bit DACs	7	Nonvolatile FLASH Memory
3	RTSI Bus Connector	8	68-pin Digital I/O Connectors
4	Field-Programmable Gate Arrays	9	68-pin Motion I/O Connectors
5	DSP		

Figure 3-3. PCI-7350 Parts Locator Diagram (Front Panel)



1	Symbol to Alert User to Read the Manual	4	Serial Number Label
2	Identification Number (used in Australia)	5	Assembly Number Label
3	Symbol Indicating CE Compliance		

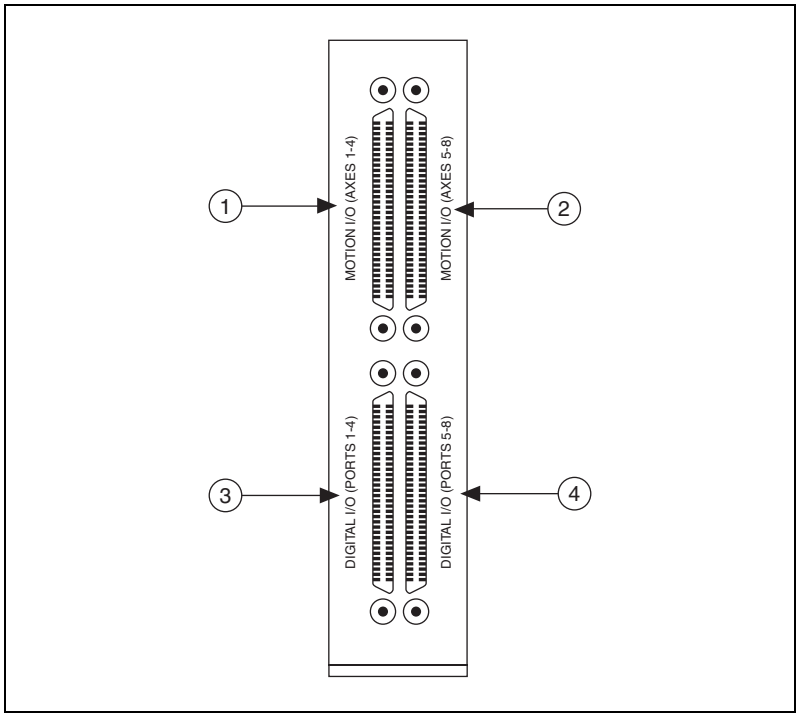
Figure 3-4. PCI-7350 Parts Locator Diagram (Back Panel)

User Connectors

The two 68-pin motion I/O connectors provide all the signals for up to eight axes of closed-loop motion control, including encoder feedback, limit and home inputs, breakpoint (position compare) outputs, trigger (position capture) inputs, and analog-to-digital (A/D) converter signals. Refer to Chapter 5, *Signal Connections*, for details about the signals in the motion I/O connectors.

The two 68-pin digital I/O connectors provide 64 bits of user-configurable digital I/O, including 12 inputs for four Hall effect sensors. Refer to Chapter 5, *Signal Connections*, for details about the signals in the digital I/O connectors.

Figure 3-5 shows the four 68-pin I/O connectors on the NI 7350 motion controller.



1	Motion I/O Connector (Axes 1–4)	3	Digital I/O Connector (Ports 1–4)
2	Motion I/O Connector (Axes 5–8)	4	Digital I/O Connector (Ports 5–8)

Figure 3-5. PXI/PCI-7350 68-pin Connectors

The RTSI connector provides up to eight triggers and one PXI star trigger (PXI-7350 only) to facilitate synchronization between multiple RTSI-enabled National Instruments products. Typical applications of the RTSI bus include triggering an image acquisition or DAQ measurement based on motion events, or capturing current motion positions based on events external to the motion controller. You also can use the RTSI bus for general hardware-based communication between RTSI devices.

4

Functional Overview

This chapter provides an overview of the National Instruments PXI/PCI-7350 controller architecture and its capabilities.

Dual Processor Architecture

The NI 7350 controller can perform up to eight axes of simultaneous motion control in a preemptive, multitasking, real-time environment.

An advanced dual-processor architecture, 32-bit CPU, digital signal processor (DSP) for embedded real-time control, and custom FPGAs give the NI 7350 controller high-performance capabilities. The powerful function set provides high-speed communications while off-loading complex motion functions from the host PC for optimized system performance.

The NI 7350 controller uses the DSP for all closed-loop control, including position tracking, PID control closed-loop computation, and motion trajectory generation. The DSP chip is supported by a custom FPGA that performs the high-speed encoder interfacing, position capture and breakpoint (position compare) functions, motion I/O processing, and stepper pulse generation for hard real-time functionality.

The embedded CPU runs a multitasking real-time operating system and handles host communications, command processing, multi-axis interpolation, onboard program execution, error handling, general-purpose digital I/O, and overall motion system integration functions.

Embedded Real-Time Operating System

The embedded firmware is based upon an embedded real-time operating system (RTOS) kernel and provides optimum system performance in varying motion applications. Motion tasks are prioritized. Task execution order depends on the priority of each task, the state of the entire motion system, I/O or other system events, and the real-time clock.

The DSP chip is a separate processor that operates independently from the CPU but is closely synchronized through interprocessor communication. The NI 7350 is a true multiprocessing and multitasking embedded controller.

The architecture of the NI 7350 controller enables advanced motion features, such as enhanced PID functions and lowpass and notch filters. Refer to the *Measurement & Automation Explorer Help for Motion* for more information about these features.

Trajectory Generators

The NI 7350 controller trajectory generators calculate the instantaneous position command that controls acceleration and velocity while it moves the axis to its target position. Depending on how you configure the axis, this command is then sent to the PID servo loop or stepper pulse generator.

To implement infinite trajectory control, the NI 7350 controller has 16 trajectory generators implemented in the DSP chip (two per axis). Each generator calculates an instantaneous position each PID update period. While simple point-to-point moves require only one trajectory generator, two simultaneous generators are required for blended moves and infinite trajectory control processing.

Analog Input and Output

The NI 7350 controller has an 8-channel multiplexed, 16-bit ADC. The converted analog values are broadcast to both the DSP and CPU using a dedicated internal high-speed serial bus. The multiplexer scan rate provides high sampling rates required for feedback loop closure, joystick inputs, or monitoring analog sensors.

For analog output, the NI 7350 uses two four-channel 16-bit DACs that are updated each PID loop.

Both the analog input and output circuitry are factory-adjusted for excellent accuracy and performance. You can use an NI-Motion VI or function to read the current temperature of the NI 7350. Refer to either the *NI-Motion Function Help* or the *NI-Motion VI Reference Help* for information about the functions and/or VIs you use to read the current temperature of the NI 7350.

Onboard Sinusoidal Commutation

The NI 7350 controller provides onboard sinusoidal commutation for axes controlling brushless DC servo motors. This feature reduces overall system cost by allowing you to use less complex, and therefore less expensive, motor drives.

Flash Memory

Nonvolatile memory on the NI 7350 controller is implemented with flash ROM, which means the controller can electrically erase and reprogram its own ROM. Because all of the embedded firmware, including the RTOS, DSP code, and the FPGA configuration file of the NI 7350 is stored in flash memory, you can upgrade the onboard firmware contents in the field for support and new-feature enhancement.

Flash memory also allows objects, such as programs and data arrays, to be stored in non-volatile memory.

It is possible to save the entire configuration state of the controller to the flash memory. On the next power cycle, the controller automatically loads and returns the configuration to these new saved default values.

Use MAX to download new firmware or save configuration defaults to flash memory.

A flash memory download utility is included with the NI-Motion software that ships with the controller.

Axes and Motion Resources

The NI 7350 controller can control up to eight axes of motion. The axes can be completely independent, simultaneously started, or mapped in multidimensional groups called coordinate spaces. You also can simultaneously start coordinate spaces for multi-vector space coordinated motion control.

Axes

At a minimum, an axis consists of a trajectory generator, a PID (for servo axes) or stepper control block, and at least one output resource—either a DAC output (for servo axes) or a stepper pulse generator output. Servo axes must also have either an encoder or ADC channel feedback resource. In addition to an encoder feedback, brushless DC servo axes also can use Hall effect sensors for initial position feedback. Closed-loop stepper axes

also require a feedback resource, while open-loop stepper axes do not. Figures 4-1 and 4-2 show these axis configurations.

With the NI 7350 controller, you can map one or two feedback resources and one or two output resources to the axis.

A stepper axis has its primary output resource mapped to a stepper output. A servo axis has its primary output resource mapped to a DAC.

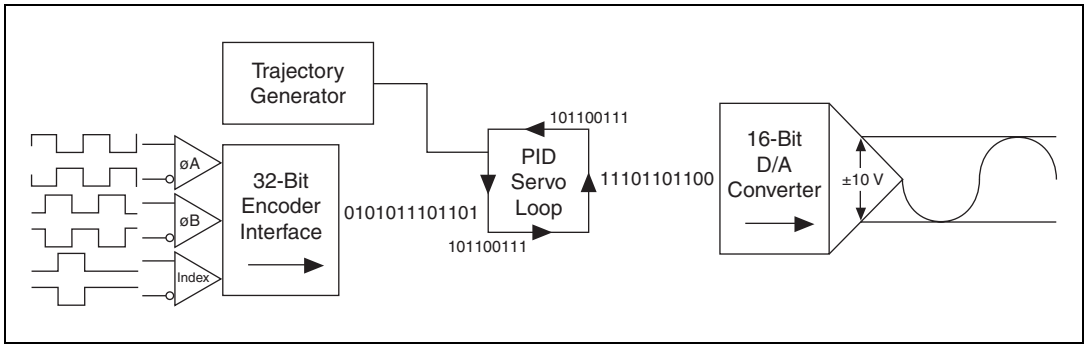


Figure 4-1. Servo Axis Resources

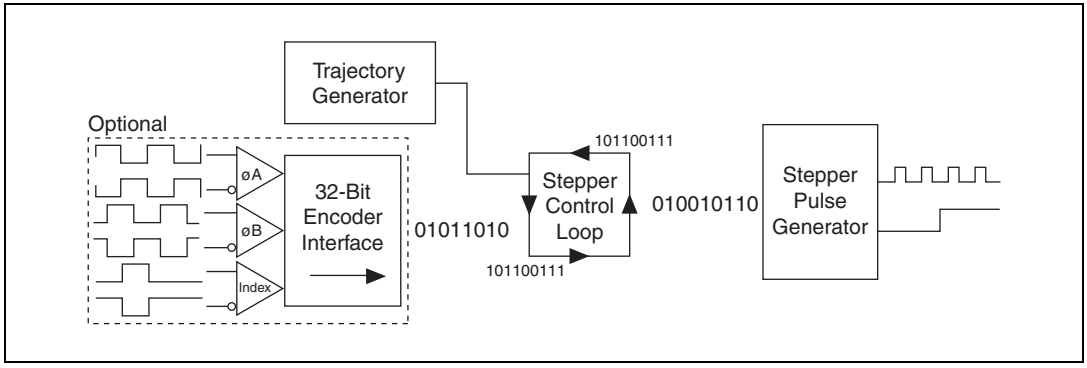


Figure 4-2. Stepper Axis Resources

The NI 7350 controller supports axes with secondary output resources. Defining two output resources is useful when controlling axes with multiple motors, such as gantry systems in which two DAC outputs can be configured with different torque limits and/or offsets. The NI 7350 controller also can use two DAC output resources when controlling a brushless DC servo axis for sinusoidal commutation.

The NI 7350 controller also supports secondary feedback resources, or encoders, for axes defined as servo. Two feedback resources are used

when implementing dual-loop control, such as in backlash compensation, which reduces the number of encoders available for other axes.

Note Refer to the *NI-Motion User Manual* for more information about configuring axes.

Motion Resources

Encoder, DAC, ADC, and motion I/O resources that are not used by an axis are available for non-axis or non-motion-specific applications. You can directly control an unmapped DAC as a general-purpose analog output (±10 V). Similarly, you can use any ADC channel to measure potentiometers or other analog sensors.

If an encoder resource is not needed for axis control, you can use it for any number of other functions, including position or velocity monitoring, as a digital potentiometer encoder input, or as a master encoder input for master/slave (electronic gearing) applications.

Each axis also has an associated forward and reverse limit input, a home input, a high-speed capture trigger input, a position breakpoint output, and an inhibit output. These signals can be used for general-purpose digital I/O when they are not being used for their motion-specific purpose.

Note When a resource is mapped to an axis, all features and functions of the resource are available as part of the axis. Because resources are referenced by axis number after they are assigned to that axis, it is not necessary to remember or use the resource number directly when accessing these features.

Onboard Programs and Buffers

You can use the real-time operating system on the NI 7350 motion controller to run custom programs. This functionality allows you to offload tasks from the host processor and onto the motion controller. Onboard programs run at the lowest priority and are therefore reserved for non-time-critical background tasks. Each program is guaranteed at least 2 ms of time every 63 ms. You can adjust the guaranteed time from 2 ms to 20 ms using the Load Program Time Slice VI or function. Refer to the *Changing a Time Slice* section of Chapter 14, *Onboard Programs*, of the *NI-Motion User Manual* for more information and the impact of changing the onboard program time slice.

You can execute the NI-Motion function set from onboard programs. In addition, the onboard programs support basic math and data operation

functions for up to 120 general-purpose variables. Refer to the *NI-Motion User Manual* for more information.

The NI 7350 also features buffered operations for contouring, high-speed position captures, and breakpoints (position compare).

You can store and run onboard programs and buffers from RAM or save them to flash ROM. The NI 7350 controller has 128 KB of RAM that is divided into two 64 KB sectors and 256 KB of ROM that is divided into four 64 KB sectors for program and buffer storage. You can store and run programs and buffers from either RAM or ROM, but you cannot split programs between the two, and you cannot split programs or buffers between the two 64 KB ROM sectors.

Note Refer to the *NI-Motion User Manual* for detailed information about the onboard programming and buffer features.

Host Communications

The host computer communicates with the controller through a number of memory port addresses on the host bus. The host bus can be either PXI or PCI.

The primary bidirectional data transfer port supports FIFO data passing in both send and readback directions. The NI 7350 controller has both a command buffer for incoming commands and a return data buffer for returning data.

The communications status register provides bits for communications handshaking as well as real-time error reporting and general status feedback to the host PC. The move complete status register provides instantaneous motion status of all axes.

The host computer also has a read-only register for reading position and velocity. This feature allows you to read the position and velocity without utilizing the onboard CPU.

5

Signal Connections

This chapter describes how to make input and output signal connections directly to the National Instruments PXI/PCI-7350 controller and briefly describes the associated I/O circuitry.

The NI 7350 controller has the following four connectors that handle all signals to and from the external motion system.

- Two 68-pin motion I/O connectors
- Two 68-pin digital I/O connectors

You can connect to the motion system with cables and accessories, varying from simple screw terminal blocks to enhanced UMI units and drives.

Caution The NI 7350 does not provide isolation between circuits.

Caution Power off all devices when connecting or disconnecting the NI 7350 controller motion I/O and auxiliary digital I/O cables. Failure to do so may damage the controller.

Motion I/O Connectors

The motion I/O connectors contain all the signals required to control up to eight axes of servo and stepper motion, including the following features:

- Motor command analog and stepper outputs
- Encoder feedback inputs
- Forward, home, and reverse limit inputs
- Breakpoint (position compare) outputs
- Trigger (position capture) inputs
- Inhibit outputs
- Controller shutdown input

The motion I/O connectors also contain up to eight channels of 16-bit A/D inputs for analog feedback or general-purpose analog input.

Figures 5-1 and 5-2 show the pin assignments for the two 68-pin motion I/O connectors on the NI 7350 controller. A signal description follows the connector pinout. In this chapter, lines above signal names indicate that the signal is active low.

Axis 1 Dir (CCW)	1	35	Axis 1 Step (CW)
Digital Ground	2	36	Axis 1 Encoder Phase A
Digital Ground	3	37	Axis 1 Encoder Phase B
Axis 1 Home Switch	4	38	Axis 1 Encoder $\overline{\text{Index}}$
$\overline{\text{Trigger 1}}$	5	39	Axis 1 Forward Limit Switch
Axis 1 $\overline{\text{Inhibit}}$	6	40	Axis 1 Reverse Limit Switch
Axis 2 Dir (CCW)	7	41	Axis 2 Step (CW)
Digital Ground	8	42	Axis 2 Encoder Phase A
Digital Ground	9	43	Axis 2 Encoder Phase B
Axis 2 Home Switch	10	44	Axis 2 Encoder $\overline{\text{Index}}$
$\overline{\text{Trigger 2}}$	11	45	Axis 2 Forward Limit Switch
Axis 2 $\overline{\text{Inhibit}}$	12	46	Axis 2 Reverse Limit Switch
Axis 3 Dir (CCW)	13	47	Axis 3 Step (CW)
Digital Ground	14	48	Axis 3 Encoder Phase A
Digital Ground	15	49	Axis 3 Encoder Phase B
Axis 3 Home Switch	16	50	Axis 3 Encoder $\overline{\text{Index}}$
$\overline{\text{Trigger 3}}$	17	51	Axis 3 Forward Limit Switch
Axis 3 $\overline{\text{Inhibit}}$	18	52	Axis 3 Reverse Limit Switch
Axis 4 Dir (CCW)	19	53	Axis 4 Step (CW)
Digital Ground	20	54	Axis 4 Encoder Phase A
Digital Ground	21	55	Axis 4 Encoder Phase B
Axis 4 Home Switch	22	56	Axis 4 Encoder $\overline{\text{Index}}$
Trigger 4	23	57	Axis 4 Forward Limit Switch
Axis 4 $\overline{\text{Inhibit}}$	24	58	Axis 4 Reverse Limit Switch
Digital Ground	25	59	Host +5 V
Breakpoint 1	26	60	Breakpoint 2
Breakpoint 3	27	61	Breakpoint 4
Digital Ground	28	62	Shutdown
Analog Output 1	29	63	Analog Output 2
Analog Output 3	30	64	Analog Output 4
Analog Output Ground	31	65	Reserved
Analog Input 1	32	66	Analog Input 2
Analog Input 3	33	67	Analog Input 4
Analog Reference (Output)	34	68	Analog Input Ground

Figure 5-1. 68-Pin Motion I/O Connector Pin Assignment for Axes 1–4

Axis 5 Dir (CCW)	1	35	Axis 5 Step (CW)
Digital Ground	2	36	Axis 5 Encoder Phase A
Digital Ground	3	37	Axis 5 Encoder Phase B
Axis 5 Home Switch	4	38	Axis 5 Encoder Index
Trigger 5	5	39	Axis 5 Forward Limit Switch
Axis 5 Inhibit	6	40	Axis 5 Reverse Limit Switch
Axis 6 Dir (CCW)	7	41	Axis 6 Step (CW)
Digital Ground	8	42	Axis 6 Encoder Phase A
Digital Ground	9	43	Axis 6 Encoder Phase B
Axis 6 Home Switch	10	44	Axis 6 Encoder Index
Trigger 6	11	45	Axis 6 Forward Limit Switch
Axis 6 Inhibit	12	46	Axis 6 Reverse Limit Switch
Axis 7 Dir (CCW)	13	47	Axis 7 Step (CW)
Digital Ground	14	48	Axis 7 Encoder Phase A
Digital Ground	15	49	Axis 7 Encoder Phase B
Axis 7 Home Switch	16	50	Axis 7 Encoder Index
Trigger 7	17	51	Axis 7 Forward Limit Switch
Axis 7 Inhibit	18	52	Axis 7 Reverse Limit Switch
Axis 8 Dir (CCW)	19	53	Axis 8 Step (CW)
Digital Ground	20	54	Axis 8 Encoder Phase A
Digital Ground	21	55	Axis 8 Encoder Phase B
Axis 8 Home Switch	22	56	Axis 8 Encoder Index
Trigger 8	23	57	Axis 8 Forward Limit Switch
Axis 8 Inhibit	24	58	Axis 8 Reverse Limit Switch
Digital Ground	25	59	Host +5 V
Breakpoint 5	26	60	Breakpoint 6
Breakpoint 7	27	61	Breakpoint 8
Digital Ground	28	62	Shutdown
Analog Output 5	29	63	Analog Output 6
Analog Output 7	30	64	Analog Output 8
Analog Output Ground	31	65	Reserved
Analog Input 5	32	66	Analog Input 6
Analog Input 7	33	67	Analog Input 8
Analog Reference (Output)	34	68	Analog Input Ground

Figure 5-2. 68-Pin Motion I/O Connector Pin Assignment for Axes 5–8

Table 5-1 describes the signals on the motion I/O connector.

Table 5-1. Motion I/O Signal Connections

Signal Name	Reference	Direction	Description
Digital Ground	—	—	Reference for digital I/O
Axis <1..8> Dir (CCW)	Digital Ground	Output	Motor direction or counterclockwise control
Axis <1..8> Step (CW)	Digital Ground	Output	Motor step or clockwise control
Axis <1..8> Encoder Phase A	Digital Ground	Input	Closed-loop only—phase A encoder input
Axis <1..8> Encoder Phase B	Digital Ground	Input	Closed-loop only—phase B encoder input
Axis <1..8> Encoder $\overline{\text{Index}}$	Digital Ground	Input	Closed-loop only—index encoder input
Axis <1..8> Home Switch	Digital Ground	Input	Home switch
Axis <1..8> Forward Limit Switch	Digital Ground	Input	Forward limit switch
Axis <1..8> Reverse Limit Switch	Digital Ground	Input	Reverse limit switch
Axis <1..8> $\overline{\text{Inhibit}}$	Digital Ground	Output	Drive inhibit
Trigger <1..8>	Digital Ground	Input	High-speed position capture trigger input <1..8>
Breakpoint <1..8>	Digital Ground	Output	Position breakpoint output <1..8>
Host +5 V	Digital Ground	Output	+5 V—host computer +5 V supply
Analog Input Ground	—	—	Reference for analog inputs
Analog Input <1..8>	Analog Input Ground	Input	16-bit analog input
Analog Output <1..8>	Analog Output Ground	Output	16-bit analog output
Analog Output Ground	—	—	Reference for analog outputs
Shutdown	Digital Ground	Input	Controlled device shutdown
Analog Reference (output)	Analog Output Ground	Output	+7.5 V—analog reference level

Motion Axis Signals

The following signals control the servo amplifier or stepper drive.

- **Analog Output <1..8>**—These 16-bit DAC outputs are typically the servo command outputs for each axis. They can drive the industry-standard ±10 V output, and can be software limited to any positive or negative voltage range desired. These outputs also feature a software-programmable voltage offset.

  Although typically used as the command output of an axis control loop, unused DACs also can function as independent analog outputs for general-purpose control.
- **Analog Reference**—For convenience, a 7.5 V (nominal) analog reference voltage is available. You can use this output as a low-current supply to sensors that require a stable reference.

Note The analog reference output is an output signal only and must not be connected to an external reference voltage. Connect the common of the external reference to the Analog Input Ground pin for proper A/D reference and improved voltage measurement.

- **Analog Output Ground**—To help keep digital noise separate from the analog DAC outputs, there is a separate return connection. Use this analog ground connection as the reference for the DAC outputs when connecting to servo amplifiers instead of the Digital Ground (digital I/O reference).
- **Axis <1..8> Step (CW) and Dir (CCW)**—These signals are the stepper command outputs for each axis. The NI 7350 controller supports both industry standards for stepper command signals—step and direction, or independent clockwise (CW) and counterclockwise (CCW) pulse outputs.

  The output configuration and signal polarity is software programmable for compatibility with various third-party drives, as follows:

  – When step and direction mode is configured, each commanded step (or microstep) produces a pulse on the step output. The direction output signal level indicates the command direction of motion, either forward or reverse.

  – CW and CCW modes produce pulses (steps) on the CW output for forward-commanded motion and pulses on the CCW output for reverse-commanded motion.

  In either case, you can set the active polarity of both outputs to active low or active high. For example, with step and direction, you can make a logic high correspond to either forward or reverse direction.

You can choose to drive the Step (CW) and Dir (CCW) outputs by using either Totem Pole mode or Open Collector mode. In Totem Pole mode, the output buffer can both sink and source current, which is appropriate for most applications. In Open Collector mode, the output buffer can only sink current. By default, Step (CW) and Dir (CCW) outputs are set to Totem Pole mode.

Caution Do *not* connect these outputs to anything other than a +5 V circuit. The output buffers will fail if subjected to voltages in excess of +5.5 V.

- **Axis <1..8> Inhibit**—Use the inhibit output signals to control the enable/inhibit function of a servo amplifier or stepper drive. When properly connected and configured, the inhibit function causes the connected motor to be de-energized and its shaft turns freely.

  You can set the inhibits to either Totem Pole or Open Collector mode. In Totem Pole mode, the inhibits can both sink and source current. In Open Collector mode, the output buffer can only sink current. By default, inhibits are set to Open Collector mode.

  Whereas the industry standard for inhibits is active low, these outputs have programmable polarity and can be set to active high for increased flexibility.

  Inhibit output signals can be activated automatically upon a Kill Motion command or any motion error that causes a kill motion condition, such as a following-error trip.

  You also can use the inhibit outputs of unused axes as general-purpose outputs. However, for safety considerations, National Instruments recommends that you use the inhibit outputs for all active axes.

Limit and Home Inputs

The following signals control limit and home inputs:

- Axis <1..8> Forward Limit Input
- Axis <1..8> Home Input
- Axis <1..8> Reverse Limit Input

These inputs are typically connected to limit switches located at physical ends of travel and/or at a specific home position. You can use software to enable and disable limit and home inputs at any time. When enabled, an active transition on a limit or home input causes a full torque halt stop of the associated axis. In addition, an active forward or reverse limit input impedes future commanded motion in that direction for as long as the signal is active.

Limit and home inputs are digitally filtered and must remain active for at least 1 ms to be recognized. Refer to Appendix A, *Specifications*, for more information. You can use MAX to disable digital filtering for limit and home inputs. Active signals should remain active to prevent motion from proceeding further into the limit. Pulsed limit signals stop motion, but they do not prevent further motion in that direction if another move is started.

The input polarity of these signals is software programmable for active low or active high.

You can use software disabled limit and home inputs as general-purpose inputs. You can read the status of these inputs at any time and set and change their polarity as required.

Limit and home inputs are a per-axis enhancement on the NI 7350 controller and are not required for basic motion control. These inputs are part of a system solution for complete motion control.

Caution National Instruments recommends using limits for personal safety, as well as to protect the motion system.

Wiring Concerns

For the end of travel limits to function correctly, the forward limit must be located at the forward or positive end of travel, and the reverse limit at the negative end of travel.

Caution Failure to follow these guidelines may result in motion that stops at, but then travels through, a limit, potentially damaging the motion system. Limits that are wired incorrectly may prevent motion from occurring at all.

Keep limit and home switch signals and their ground connections wired separately from the motor drive/amplifier signal and encoder signal connections.

Caution Wiring these signals near each other can cause faulty motion system operation that is due to signal noise and crosstalk.

Limit and Home Input Circuit

Limit and home inputs have an onboard pull-up resistor. If left floating, the inputs are interpreted as a high logic level.

Caution Excessive input voltages can cause erroneous operation and/or component failure. Verify that the input voltage is within the specification range.

Encoder Signals

The NI 7350 controller offers up to eight channels of single-ended quadrature encoder inputs. All National Instruments power drives and UMI accessories provide built-in circuitry that converts differential encoder signals to single-ended encoder signals. Each channel consists of a Phase A, Phase B, and Index input, as described in the following sections.

Axis <1..8> Encoder Phase A/Phase B

The encoder inputs provide position and velocity feedback for absolute and relative positioning of axes in any motion system configuration.

If an encoder resource is not needed for axis control, it is available for other functions including position monitoring, digital potentiometer encoder inputs, or as a master encoder input for master/slave (electronic gearing) applications.

The encoder channels (Axis <1..8> Encoder Phase A/Phase B) are implemented in an FPGA and provide advanced features, such as high-speed position capture inputs and position breakpoint outputs. The encoders have a maximum count frequency of 20 MHz.

An encoder input channel converts quadrature signals on Phase A and Phase B into 32-bit up/down counter values. Quadrature signals are generated by optical, magnetic, laser, or electronic devices that provide two signals, Phase A and Phase B, that are 90° out of phase. The leading phase, A or B, determines the direction of motion. The four transition states of the relative signal phases provide distinct pulse edges that cause count up or count down pulses in the direction determined by the leading phase.

A typical encoder with a specification of N (N = number) lines per unit of measure, which can be revolutions or linear distance, produces $4 \times N$ quadrature counts per unit of measure. The count is the basic increment of position in National Instruments motion systems.

Note If your encoder does not supply resolution in quadrature counts per revolution, determine quadrature counts per revolution by multiplying the encoder resolution, in encoder lines or periods, by 4. The encoder resolution is the number of encoder lines between consecutive encoder indexes, such as marker or Z-bit. If the encoder does not have an index output, the resolution is referred to as lines per revolution, or lines per unit of

measure—inch, centimeter, millimeter, and so on. For example, a 500 line encoder has 2,000 quadrature counts per revolution.

Axis <1..8> Encoder Index

The Index input is primarily used to establish a reference position. This function uses the number of counts per revolution or the linear distance to initiate a search move that locates the index position. When a valid index signal transition occurs during a find reference routine, the position of the index signal is captured accurately. Use this captured position to establish a reference zero position for absolute position control or any other motion system position reference required.

The default MAX settings guarantee that the find index routine completes successfully if the encoder generates a high index pulse when phases A and B are low and the encoder is connected through an NI UMI or drive accessory. Figure 5-3 shows the default encoder phasing diagram at the inputs to an NI UMI or drive accessory.

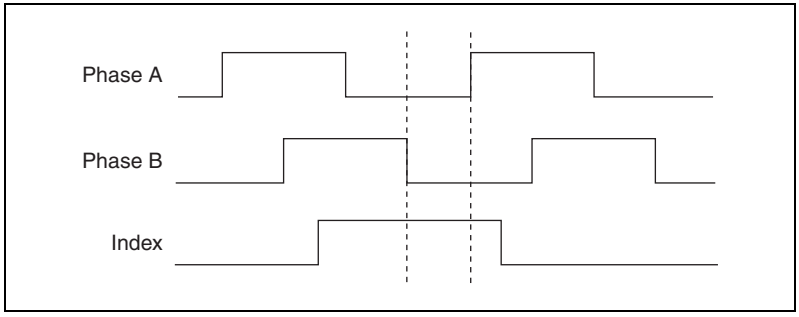


Figure 5-3. Quadrature Encoder Phasing Diagram

You can set the index reference criteria in MAX to change the pattern of phases A and B for the index search. You also can set the encoder polarity for phases A, B, and I in MAX.

Wiring Concerns

The encoder inputs are connected to quadrature decoder/counter circuits. It is very important to minimize noise at this interface. Excessive noise on these encoder input signals may result in loss of counts or extra counts and erroneous closed-loop motion operation. Verify the encoder connections before powering up the system.

Caution Wire encoder signals and their ground connections separately from all other connections. Wiring these signals near the motor drive/amplifier or other signals can cause positioning errors and faulty operation.

National Instruments strongly recommends you use encoders with differential line drive outputs for all applications. You *must* use differential encoders if the encoder cable length is longer than 3.05 m (10 ft). Shielded, 24 AWG wire is the minimum recommended size for the encoder cable. Cables with twisted pairs and an overall shield are recommended for optimized noise immunity.

All National Instruments power drives and UMI accessories provide built-in circuitry that converts differential encoder signals to single-ended encoder signals.

Caution Unshielded cables can cause noise to corrupt the encoder signals, resulting in lost or additional counts and reduced motion system accuracy.

Encoder Input Circuit

The Phase A, Phase B, and Index encoder inputs all have an onboard pull-up resistor, and are interpreted as high logic level if left floating. Both phases A and B are required for proper encoder counter operation, and the signals must support the 90° phase difference within system tolerance. The encoder and Index signals are conditioned by a software-programmable digital filter inside the FPGA. The Index signal is optional but highly recommended and is required for initialization functionality with the Find Reference function.

Trigger Inputs, Shutdown Input, and Breakpoint Outputs

The NI 7350 controller offers additional high-performance encoder features. The encoder channels have high-speed position capture trigger inputs and position breakpoint outputs. These signals are useful for high-speed synchronization of motion with actuators, sensors, and other parts of the complete motion system.

- **Trigger Input <1..8>**—When enabled, an active transition on a high-speed position capture input causes instantaneous position capture of the corresponding encoder count value. You can use this high-speed position capture functionality for applications ranging from simple position tagging of sensor data to complex camming systems with advance/retard positioning and registration. An available NI 7350 controller position mode is to move an axis relative to a captured position.

The polarity of the trigger (position capture) input is programmable in software as active low, or active high, rising edge or falling edge. You also can use a trigger (position capture) input as a latching general-purpose digital input by simply ignoring the captured position.

- **Shutdown Input**—When enabled in software, the shutdown input signal can be used to kill all motion by asserting the controller inhibits, setting the analog outputs to 0 V, and stopping any stepper pulse generation. To activate shutdown, the signal must transition from a low to high state.
- **Breakpoint <1..8>**—You can program a breakpoint (position compare) output to transition when the associated encoder value equals the breakpoint (position compare) position. You can use a breakpoint (position compare) output to directly control actuators or as a trigger to synchronize data acquisition or other functions in the motion control system.

  You can program breakpoints as either *absolute*, *relative*, *periodic*, or *buffered* positions. Breakpoint (position compare) outputs can be preset to a known state so that the transition when the breakpoint (position compare) occurs can be low to high, high to low, toggle, or pulse.

  You can set the breakpoint (position compare) outputs to Totem Pole mode or Open Collector mode. In Totem Pole mode, the output buffer can both sink and source current, which is appropriate for most applications. In Open Collector mode, the output buffer can only sink current. By default, breakpoint (position compare) outputs are set to Totem Pole mode.

  You can directly set and reset breakpoint (position compare) outputs to use them as general-purpose digital outputs.

Wiring Concerns

Caution Keep trigger (position capture) input, shutdown input, and breakpoint (position compare) output signals and their ground connections wired separately from the motor drive/amplifier signal and encoder signal connections. Wiring these signals near each other can cause faulty operation.

Caution Excessive input voltages can cause erroneous operation and/or component failure.

Trigger Input and Shutdown Input Circuits

Trigger (position capture) input and shutdown input circuits have onboard pull-up resistors, and are interpreted as high logic level if left floating.

Analog Inputs

The NI 7350 controller has the following ADC input signals:

- **Analog Input <1..8>**—The NI 7350 controller includes an eight-channel multiplexed, 16-bit ADC capable of measuring ±10 V, ±5 V, 0–10 V, and 0–5 V inputs.

  You can configure each ADC channel for motion feedback, simple A/D conversion, or both.

  You can read the digital value of analog voltage on any of the ADC channels of the controller by using the Read ADC function. Table 5-2 shows the range of values read back and the voltage resolution for each setting. The voltage resolution is in microvolts per least significant bit (µV/LSB).

Table 5-2. Analog Input Voltage Ranges

Input Range	Binary Values	Resolution
±10 V	–32,768 to 32,767	305 µV/LSB
±5 V	–32,768 to 32,767	153 µV/LSB
0–10 V	0 to 65,535	153 µV/LSB
0–5 V	0 to 65,535	76 µV/LSB

  When configured as analog feedback, an analog sensor acts like a limited range absolute position device with a full-scale position range. You can map any ADC channel as feedback to any axis.

  You can enable and disable individual ADC channels in software. Disable unused ADC channels for the highest multiplexer scan rate performance. Properly enabled, the scan rate is high enough to support analog feedback at the highest PID sample rate.

- **Analog Input Ground**—To help keep digital noise out of the analog input, a separate return connection is available. Use this reference ground connection and not Digital Ground (digital I/O reference) or Analog Output Ground as the reference for the analog inputs.

Wiring Concerns

For proper use of each ADC input channel, the analog signal should be a floating source with the positive terminal connected to the channel input and the negative terminal connected to analog input ground. Figure 5-4 shows a simplified schematic diagram of this connection.

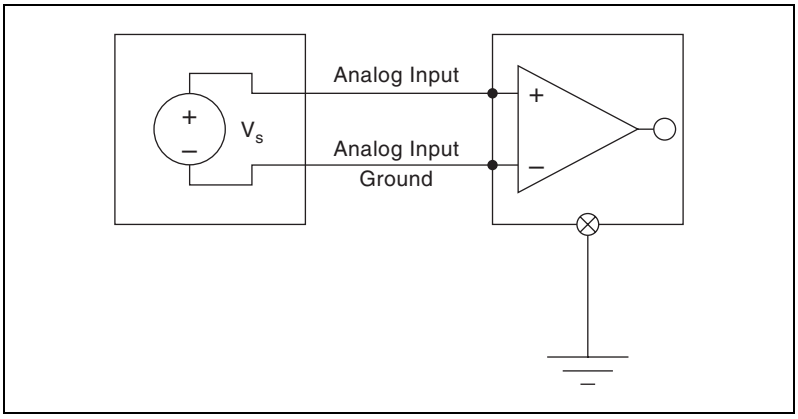


Figure 5-4. Analog Input Connectivity

Other Motion I/O Connection

The NI 7350 controller provides the host +5 V signal, which is the internal +5 V supply of the host computer. This signal is typically used to detect when the host computer is powered on and to shut down external motion system components when the host computer is powered off or disconnected from the motion accessory.

Caution The host +5 V signal is limited and should not be used to power any external devices, except those intended in the host bus monitor circuits on the UMI and drive products.

Interfacing With Optocouplers

Many motor drive manufacturers offer opto-isolated inputs for Step (CW)/Dir (CCW) and other motion control signals. The NI 7350 is well-suited to drive most of these inputs directly when you connect the controller output signal to the positive side of the optocoupler input and connect the controller GND to the negative side of the optocoupler input. This method works if the optocoupler is designed to work with a 5 V signal, requires less than 16 mA, and the NI 7350 output is configured for Totem Pole output mode. Figure 5-5 shows a typical optocoupler wiring example.

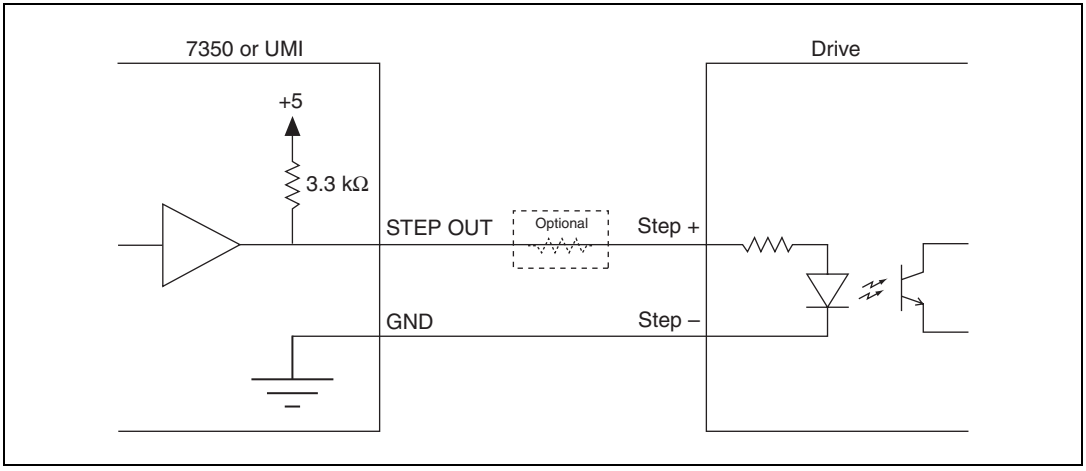


Figure 5-5. Typical Optocoupler Wiring (Totem Pole Output Mode)

In some rare circumstances, the optocoupler will not work with a 5 V signal, or it requires more current than the maximum current level the controller can provide. In this case, connect the controller output to the negative side of the optocoupler input, connect the positive side of the input to a supply as specified by the drive manufacturer, and configure the controller output for Open Collector mode. Figure 5-6 shows this special case wiring example.

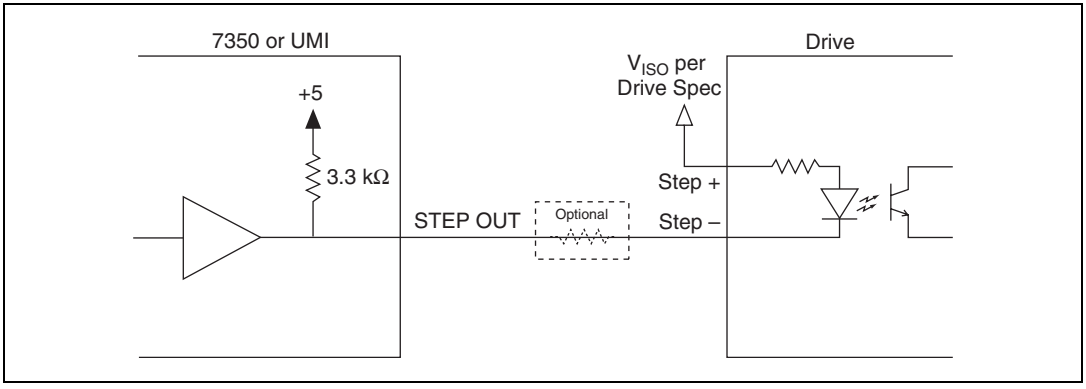


Figure 5-6. Special Case Optocoupler Wiring (Open-Collector Output Mode)

Caution If the optocoupler input does not include its own current-limiting resistor, you must provide an external resistor in series with the NI 7350 output. To prevent damage to the NI 7350 controller or other motion hardware, use a resistor that limits the current to a value below the maximum specifications of the controller and other hardware.

Digital I/O Connector

The general-purpose digital I/O lines on the NI 7350 controller are available on two separate 68-pin digital I/O connectors. Figures 5-7 and 5-8 show the pin assignments for these connectors.

+5 V	1	35	Digital Ground
PCLK	2	36	Digital Ground
Reserved	3	37	Digital Ground
Reserved	4	38	DPull (P1:P4)
PWM1	5	39	Digital Ground
Reserved	6	40	Reserved
Reserved	7	41	Digital Ground
Reserved	8	42	Digital Ground
PWM2	9	43	Digital Ground
Port 1:bit 0	10	44	Port 1:bit 1
Digital Ground	11	45	Port 1:bit 2
Port 1:bit 3	12	46	Digital Ground
Port 1:bit 4	13	47	Port 1:bit 5
Digital Ground	14	48	Port 1:bit 6
Port 1:bit 7	15	49	Digital Ground
Port 2:bit 0	16	50	Digital Ground
Port 2:bit 1	17	51	Port 2:bit 2
Digital Ground	18	52	Port 2:bit 3
Digital Ground	19	53	Port 2:bit 4
Digital Ground	20	54	Port 2:bit 5
Port 2:bit 6	21	55	Digital Ground
Port 2:bit 7	22	56	Digital Ground
Port 3:bit 0	23	57	Port 3:bit 1
Digital Ground	24	58	Port 3:bit 2
Port 3:bit 3	25	59	Digital Ground
Port 3:bit 4	26	60	Port 3:bit 5
Digital Ground	27	61	Port 3:bit 6
Port 3:bit 7	28	62	Digital Ground
Port 4:bit 0	29	63	Port 4:bit 1
Digital Ground	30	64	Port 4:bit 2/Axis 1, Hall 1
Axis 1, Hall 2/Port 4:bit 3	31	65	Digital Ground
Axis 1, Hall 3/Port 4:bit 4	32	66	Port 4:bit 5/Axis 2, Hall 1
Digital Ground	33	67	Port 4:bit 6/Axis 2, Hall 2
Axis 2, Hall 3/Port 4:bit 7	34	68	Digital Ground

Figure 5-7. 68-Pin Digital I/O Connector Pin Assignments (Ports 1–4)

+5 V	1	35	Digital Ground
Reserved	2	36	Digital Ground
Reserved	3	37	Digital Ground
Reserved	4	38	DPull (P5:P8)
Reserved	5	39	Digital Ground
Reserved	6	40	Reserved
Reserved	7	41	Digital Ground
Reserved	8	42	Digital Ground
Reserved	9	43	Digital Ground
Port 5:bit 0	10	44	Port 5:bit 1
Digital Ground	11	45	Port 5:bit 2
Port 5:bit 3	12	46	Digital Ground
Port 5:bit 4	13	47	Port 5:bit 5
Digital Ground	14	48	Port 5:bit 6
Port 5:bit 7	15	49	Digital Ground
Port 6:bit 0	16	50	Digital Ground
Port 6:bit 1	17	51	Port 6:bit 2
Digital Ground	18	52	Port 6:bit 3
Digital Ground	19	53	Port 6:bit 4
Digital Ground	20	54	Port 6:bit 5
Port 6:bit 6	21	55	Digital Ground
Port 6:bit 7	22	56	Digital Ground
Port 7:bit 0	23	57	Port 7:bit 1
Digital Ground	24	58	Port 7:bit 2
Port 7:bit 3	25	59	Digital Ground
Port 7:bit 4	26	60	Port 7:bit 5
Digital Ground	27	61	Port 7:bit 6
Port 7:bit 7	28	62	Digital Ground
Port 8:bit 0	29	63	Port 8:bit 1
Digital Ground	30	64	Port 8:bit 2/Axis 3, Hall 1
Axis 3, Hall 2/Port 8:bit 3	31	65	Digital Ground
Axis 3, Hall 3/Port 8:bit 4	32	66	Port 8:bit 5/Axis 4, Hall 1
Digital Ground	33	67	Port 8:bit 6/Axis 4, Hall 2
Axis 4, Hall 3/Port 8:bit 7	34	68	Digital Ground

Figure 5-8. 68-Pin Digital I/O Connector Pin Assignments (Ports 5–8)

The 64-bit digital I/O ports are configured in hardware as up to eight 8-bit digital I/O ports. The bits in a port are typically controlled and read with byte-wide bitmapped commands.

Bits 2–7 in DIO ports 4 and 8 are dual-purpose bits that can be used for either general-purpose I/O or Hall sensor feedback during system configuration and initialization, but not both. When you set these bits to provide Hall sensor feedback, they are reserved for this activity and cannot be used for general-purpose I/O until you reinitialize the motion system.

All digital I/O lines have programmable direction and polarity.

The DPull(P1:P4) and DPull(P5:P8) pins control the state of the digital input pins at power-up.

Connecting DPull(P1:P4) to +5 V or leaving it unconnected configures all pins in ports 1–4 for 10 kΩ pull-ups. Connecting DPull(P1:P4) to ground configures these ports for 10 kΩ pull-downs.

Connecting DPull(P5:P8) to +5 V or leaving it unconnected configures all pins in ports 5–8 for 10 kΩ pull-ups. Connecting DPull(P5:P8) to ground configures these ports for 10 kΩ pull-downs.

PWM Features

The NI 7350 controller provides two pulse width modulation (PWM) outputs on the digital I/O connector for ports 1–4. The PWM outputs generate periodic waveforms whose period and duty cycles can be independently controlled through software commands. You can compare PWM to a digital representation of an analog value, because the duty cycle is directly proportional to the desired output value. PWM outputs are typically used for transmitting an analog value through an optocoupler. A simple lowpass filter turns a PWM signal back into its corresponding analog value. If appropriate, you can use an external clock source connected to the PCLK input instead of the internal source as the clock for the PWM generators.

Note These signals are configured in software and are in no way associated with the PID servo control loop. Refer to the *Measurement & Automation Explorer Help for Motion*, the *NI-Motion Function Help*, or the *NI-Motion VI Help* for more information.

RTSI Connector

The PXI-7350 uses the PXI chassis backplane to connect to other RTSI-capable devices.

The PCI-7350 uses a ribbon cable to connect to other RTSI-capable PCI devices.

RTSI Signal Considerations

The NI 7350 controller allows you to use up to eight RTSI trigger lines as sources for trigger inputs, or as destinations for breakpoint (position compare) outputs and encoder signals. The RTSI trigger lines also can serve as a generic digital I/O port. The RTSI star trigger line, which is available only on the PXI-7350, can be used only for a trigger input. Breakpoint (position compare) outputs are output-only signals that generate an active high pulse of 200 ns duration across RTSI.

Encoder and Index signals are output-only signals across RTSI that are the digitally-filtered versions of the raw signals coming into the controller. If you are using the RTSI bus for motion I/O or generic digital I/O, all signals are passed through unaltered.

A

Specifications

This appendix lists the hardware and software performance specifications for the PXI/PCI-7350 controller. Hardware specifications are typical at 25 °C, unless otherwise stated.

Servo Performance

PID update rate range ..... 62.5µs/sample to 5 ms/sample
- Max PID update rate ..... 62.5 µs per 2 axes
- 8-axis PID update rate ..... 250 µs total

Trajectory update rate ..... Same as PID update rate

Multi-axis synchronization ..... <1 update sample

Position accuracy
- Encoder feedback ..... ±1 quadrature count
- Analog feedback ..... ±1 LSB

Double-buffered trajectory parameters
- Absolute position range ..... $\pm 2^{31}$ counts
- Max relative move size ..... $\pm 2^{31}$ counts
- Velocity range ..... 1 to ±20,000,000 counts/s
- RPM range[1] ..... ±1,200,000 revolutions/min
- Acceleration/deceleration[2] ..... 244 to 512,000,000 counts/s^2 at a PID update rate of 250 µs
- RPS/s range[1] ..... ±256,000 revolutions/s^2
- S-Curve time range ..... 1 to 32,767 samples
- Following error range ..... 0 to 32,767 counts
- Gear ratio ..... ±32,767:1 to ±1:32,767

[1] Assumes a 2,000-count encoder.

[2] Refer to the *NI-Motion User Manual* for more information.

Servo control loop modes .....PID, PIVff, S-Curve, Dual Loop
- PID (Kp, Ki, and Kd) gains .....0 to 32,767
- Integration limit (Ilim).....0 to 32,767
- Derivative sample period (Td).....1 to 63 samples
- Feedforward (Aff, Vff) gains .....0 to 32,767
- Velocity feedback (Kv) gain .....0 to 32,767

Servo command analog outputs
- Voltage range.....±10 V
- Resolution.....16 bits (0.000305 V/LSB)
- Programmable torque (velocity) limits
  - Positive limit .....±10 V (–32,768 to +32,767)
  - Negative limit.....±10 V (–32,768 to +32,767)
- Programmable offset .....±10 V (–32,768 to +32,767)

Stepper Performance

Trajectory update rate range .....62.5 to 500 µs/sample
- Max update rate .....62.5 µs per 2 axes
- 8-axis update rate.....250 µs total

Multi-axis synchronization .....<1 update sample

Position accuracy
- Open-loop stepper .....1 full, half, or microstep
- Encoder feedback .....±1 quadrature count
- Analog feedback.....±1 LSB

Double-buffered trajectory parameters
- Position range .....$\pm 2^{31}$ steps
- Max relative move size.....$\pm 2^{31}$ steps
- Velocity range .....1 to 8,000,000 steps/s
- RPM range[1] .....±1,200,000 revolutions/min
- Acceleration/deceleration[2].....244 to 512,000,000 steps/s^2 at a PID update rate of 250 µs
- RPS/s range[1] .....±256,000 revolutions/s^2

[1] Assumes a 2,000-count encoder.

[2] Refer to the *NI-Motion User Manual* for more information.

S-curve time range ..... 1 to 32,767 samples
Following error range ..... 0 to 32,767 counts
Gear ratio ..... ±32,767:1 to ±1:32,767

Stepper outputs
Max pulse rate ..... 8 MHz (full, half, and microstep)
Max pulse width ..... 6.5 µs at <40 kHz
Min pulse width ..... 40 ns at >4 MHz
Step output mode ..... Step and direction or CW/CCW
Voltage range ..... 0 to 5 V
Output low voltage ..... 0.6 V at 64 mA sink
Output high voltage ..... Totem Pole: 2V at 16 mA source; open collector: built-in 3.3 kΩ pull-up to +5 V
Polarity ..... Programmable, active high or active low

System Safety

Watchdog timer function ..... Resets board to startup state
Watchdog timeout ..... 63 or 256 ms, programmable

Shutdown input
Voltage range ..... 0 to 5 V
Input low voltage ..... 0.8 V
Input high voltage ..... 2 V
Built-in pull-up resistor ..... 3.3 kΩ to +5 V
Polarity ..... Rising edge
Control ..... Disable all axes and command outputs; resets I/O to default states

Host +5 V max current sourced from controller ..... 100 mA at 5 V

Motion I/O

Encoder inputs ..... Quadrature, incremental, single-ended
Max count rate ..... 20 MHz

Min pulse width.....Programmable; depends on digital filter settings
Voltage range.....0 to 5 V
Input low voltage.....0.8 V
Input high voltage.....2 V
Built-in pull-up resistor .....3.3 kΩ to +5 V
Min index pulse width.....Programmable; depends on digital filter settings

Forward, reverse, and home inputs
Number of inputs.....3 per axis, up to 24
Voltage range.....0 to 5 V
Input low voltage.....0.8 V
Input high voltage.....2 V
Built-in pull-up resistor .....3.3 kΩ to +5 V
Polarity .....Programmable, active high or active low
Min pulse width
Limit filters enabled .....1 ms
Limit filters disabled .....50 ns
Control.....Individual enable/disable, stop on input, prevent motion, Find Reference

Trigger (position capture) inputs
Number of inputs.....Up to 8 (Encoders 1 through 8)
Voltage range.....0 to 5 V
Input low voltage.....0.8 V
Input high voltage.....2 V
Built-in pull-up resistor .....3.3 kΩ to +5 V
Polarity .....Programmable, active high or active low
Min pulse width.....100 ns
Max capture latency .....100 ns
Capture accuracy .....1 count
Max capture rate (non-buffered) .....150 Hz

Max buffered capture rate[1] ..... 2 kHz per axis

Breakpoint (position compare) outputs

Number of outputs ..... Up to 8 (Encoders 1 through 8)

Voltage range ..... 0 to 5 V

Output low voltage ..... 0.6 V at 64 mA sink

Output high voltage ..... Totem Pole: 2 V at 16 mA source; open collector: built-in 3.3 kΩ pull-up to +5 V

Polarity ..... Programmable, active high or active low

Max trigger rate (non-buffered) ..... 150 Hz

Max buffered trigger rate[1] ..... 2 kHz per axis

Max periodic rate ..... 4 MHz per axis

Minimum pulse width (pulse mode only) ..... 200 ns

Inhibit/enable output

Number of outputs ..... 1 per axis, up to 8

Voltage range ..... 0 to 5 V

Output low voltage ..... 0.6 V at 64 mA sink

Output high voltage ..... Totem Pole: 2 V at 16 mA source; open collector: built-in 3.3 kΩ pull-up to +5 V

Polarity ..... Programmable, active high or active low

Control ..... MustOn/MustOff or automatic when axis off

Analog inputs

Control ..... Assigned to axis for analog feedback or general-purpose analog input

Number of inputs ..... Up to 8, multiplexed, single-ended

Multiplexer scan rate ..... 25 µs per enabled ADC

[1] Assumes a PID update rate of 250 µs. 2 kHz per axis for PID rates between 62.5 and 250 µs, and 1 kHz per axis for PID rates greater than 250 µs. This value is not to exceed 8 kHz total for all ongoing buffered breakpoint (position compare) and trigger (position capture) operation.

Input coupling.....DC
Input impedance .....100 MΩ min
Voltage range (programmable).....±10 V, ±5 V, 0–10 V, 0–5 V
Bandwidth.....234 kHz
Resolution.....16 bits, no missing codes
Monotonicity .....Guaranteed
Absolute accuracy
all ranges.....0.5% of full-scale

System noise
±10 V.....220 µVrms, typical
±5 V.....120 µVrms, typical
0–10 V.....130 µVrms, typical
0–5 V.....60 µVrms, typical

Maximum working voltage .....±11 V

Overvoltage protection
Powered on.....±25 V
Powered off .....±15 V

Analog outputs
Number of outputs.....Up to 8, single-ended
Output coupling.....DC
Voltage range.....±10 V
Output current.....±5 mA
Minimum load .....2 kΩ at full-scale
Resolution.....16 bits, no missing codes
Monotonicity .....Guaranteed
Absolute accuracy .....0.5% of full-scale
Noise.....100 µVrms Max
Protection.....Short-circuit to ground
Settling time.....15 µs, full-scale step
Analog reference output voltage .....7.5 V (nominal)
Analog reference output current.....5 mA

Onboard temperature sensor accuracy.....±4 °C

Digital I/O

Ports ..... Up to 8 8-bit ports
- Line direction ..... Individual bit programmable

Inputs
- Voltage range ..... 0 to 5 V
  - Input low voltage ..... 0.8 V
  - Input high voltage ..... 2.0 V
- Polarity ..... Programmable, active high or active low

Built-in pull-up resistor ..... 10 kΩ, configurable pull-up to +5 V or pull-down to GND

Outputs
- Voltage range ..... 0 to 5 V
  - Output low voltage ..... 0.45 V at 24 mA
  - Output high voltage ..... 2.4 V at 24 mA
- Max total DIO current
  - Sourced from controller ..... 1 A
- Polarity ..... Programmable, active high or active low
- PWM outputs
  - Number of PWM outputs 2
  - Max PWM frequency ..... 50 kHz
  - Resolution 8-bit
  - Duty cycle range ..... 0 to (255/256)%
  - Clock sources ..... Internal or external

RTSI

Trigger lines 8

PXI Star Trigger (PXI-7350 only) 1

Maximum Power Requirements

+3.3 V (±10%).....2 A

+5 V (±5%).....2 A

+12 V (±5%).....30 mA

–12 V (±10%).....0 mA

Power consumption .....18 W

Physical

Dimensions (Not Including Connectors)

PXI-7350 .....16 cm × 10 cm (6.3 in. × 3.9 in.)

PCI-7330.....17.5 cm × 9.9 cm
(6.9 in. × 3.9 in.)

Connectors

Motion I/O connectors.....2 68-pin female high-density VHDCI type

32-bit digital I/O connectors.....2 68-pin female high-density VHDCI type

RTSI connector (PCI-7350 only) .....37-pin male for ribbon cable

Weight

PXI-7350 .....170 g (6 oz)

PCI-7350.....113 g (4 oz)

Maximum Working Voltage

Channel-to-earth	11 V, Installation Category I (signal voltage plus common-mode voltage)
Channel-to-channel	22 V, Installation Category I (signal voltage plus common-mode voltage)

Caution These values represent the maximum allowable voltage between any accessible signals on the controller. To determine the acceptable voltage range for a particular signal, refer to the individual signal specifications.

Environment

Operating temperature	0 to 55 °C
Storage temperature	–20 to 70 °C
Humidity	10 to 90% RH, noncondensing
Maximum altitude	2,000 m
Pollution Degree	2

Safety

This product is designed to meet the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CAN/CSA-C22.2 No. 61010-1

Note For UL and other safety certifications, refer to the product label or visit `ni.com/certification`, search by model number or product line, and click the appropriate link in the Certification column.

Electromagnetic Compatibility

This product is designed to meet the requirements of the following standards of EMC for electrical equipment for measurement, control, and laboratory use:

- EN 61326 EMC requirements; Minimum Immunity
- EN 55011 Emissions; Group 1, Class A
- CE, C-Tick, ICES, and FCC Part 15 Emissions; Class A

Note For EMC compliance, operate this device according to product documentation.

CE Compliance

This product meets the essential requirements of applicable European Directives, as amended for CE marking, as follows:

- 73/23/EEC; Low-Voltage Directive (safety)
- 89/336/EEC; Electromagnetic Compatibility Directive (EMC)

Note Refer to the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, visit `ni.com/certification`, search by model number or product line, and click the appropriate link in the Certification column.

Waste Electrical and Electronic Equipment (WEEE)

EU Customers At the end of their life cycle, all products *must* be sent to a WEEE recycling center. For more information about WEEE recycling centers and National Instruments WEEE initiatives, visit `ni.com/environment/weee.htm`.

B

Cable Connector Descriptions

This appendix describes the connector pinout for the cables that connect to the PXI/PCI-7350 controller.

Figures B-1 and B-2 show the pin assignments for the stepper 50-pin motion connectors, while Figures B-3 and B-4 show the pin assignments for the servo 50-pin motion connectors. These connectors are available when you use the SH68-C68-S shielded cable assembly and the 68M-50F step/servo bulkhead cable adapter. You can order the cable assembly and cable adapter from `ni.com`. The following list includes part numbers for each of these products:

- 2m SHC68-C68-S Cable (part number 186380-02)
- 0.5m SHC68-C68-S Cable (part number 186380-0R5)
- 68M-50F Extended I/O Cable Adapter (part number 184670-02)

Axis 1 Dir (CCW)	1	2	Axis 1 Step (CW)
Digital Ground	3	4	Axis 1 Encoder Phase A
Digital Ground	5	6	Axis 1 Encoder Phase B
Axis 1 Home Switch	7	8	Axis 1 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 1	9	10	Axis 1 Forward Limit Switch
Axis 1 $\overline{\text{Inhibit}}$	11	12	Axis 1 Reverse Limit Switch
Axis 2 Dir (CCW)	13	14	Axis 2 Step (CW)
Digital Ground	15	16	Axis 2 Encoder Phase A
Digital Ground	17	18	Axis 2 Encoder Phase B
Axis 2 Home Switch	19	20	Axis 2 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 2	21	22	Axis 2 Forward Limit Switch
Axis 2 $\overline{\text{Inhibit}}$	23	24	Axis 2 Reverse Limit Switch
Axis 3 Dir (CCW)	25	26	Axis 3 Step (CW)
Digital Ground	27	28	Axis 3 Encoder Phase A
Digital Ground	29	30	Axis 3 Encoder Phase B
Axis 3 Home Switch	31	32	Axis 3 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 3	33	34	Axis 3 Forward Limit Switch
Axis 3 $\overline{\text{Inhibit}}$	35	36	Axis 3 Reverse Limit Switch
Axis 4 Dir (CCW)	37	38	Axis 4 Step (CW)
Digital Ground	39	40	Axis 4 Encoder Phase A
Digital Ground	41	42	Axis 4 Encoder Phase B
Axis 4 Home Switch	43	44	Axis 4 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 4	45	46	Axis 4 Forward Limit Switch
Axis 4 $\overline{\text{Inhibit}}$	47	48	Axis 4 Reverse Limit Switch
Digital Ground	49	50	Host +5 V

Figure B-1. 50-Pin Stepper Connector Pin Assignment (Axes 1–4)

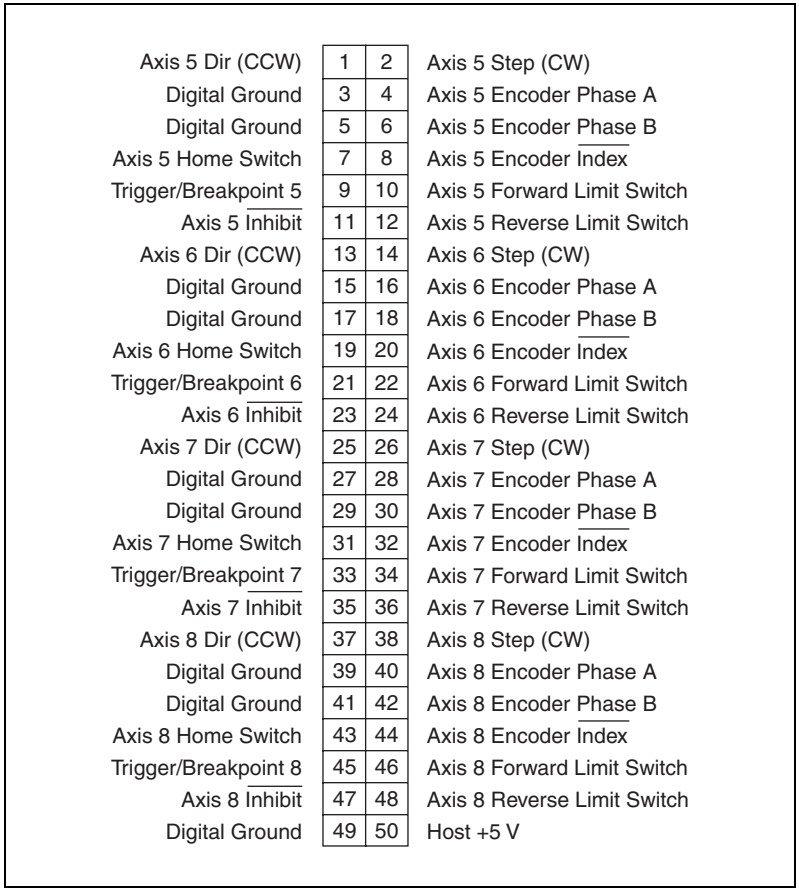

Axis 5 Dir (CCW) 1 2 Axis 5 Step (CW)
Digital Ground 3 4 Axis 5 Encoder Phase A
Digital Ground 5 6 Axis 5 Encoder Phase B
Axis 5 Home Switch 7 8 Axis 5 Encoder Index
Trigger/Breakpoint 5 9 10 Axis 5 Forward Limit Switch
Axis 5 Inhibit 11 12 Axis 5 Reverse Limit Switch
Axis 6 Dir (CCW) 13 14 Axis 6 Step (CW)
Digital Ground 15 16 Axis 6 Encoder Phase A
Digital Ground 17 18 Axis 6 Encoder Phase B
Axis 6 Home Switch 19 20 Axis 6 Encoder Index
Trigger/Breakpoint 6 21 22 Axis 6 Forward Limit Switch
Axis 6 Inhibit 23 24 Axis 6 Reverse Limit Switch
Axis 7 Dir (CCW) 25 26 Axis 7 Step (CW)
Digital Ground 27 28 Axis 7 Encoder Phase A
Digital Ground 29 30 Axis 7 Encoder Phase B
Axis 7 Home Switch 31 32 Axis 7 Encoder Index
Trigger/Breakpoint 7 33 34 Axis 7 Forward Limit Switch
Axis 7 Inhibit 35 36 Axis 7 Reverse Limit Switch
Axis 8 Dir (CCW) 37 38 Axis 8 Step (CW)
Digital Ground 39 40 Axis 8 Encoder Phase A
Digital Ground 41 42 Axis 8 Encoder Phase B
Axis 8 Home Switch 43 44 Axis 8 Encoder Index
Trigger/Breakpoint 8 45 46 Axis 8 Forward Limit Switch
Axis 8 Inhibit 47 48 Axis 8 Reverse Limit Switch
Digital Ground 49 50 Host +5 V

Figure B-2. 50-Pin Stepper Connector Pin Assignment (Axes 5–8)

Analog Output Ground	1	2	Analog Output 1
Digital Ground	3	4	Axis 1 Encoder Phase A
Digital Ground	5	6	Axis 1 Encoder Phase B
Axis 1 Home Switch	7	8	Axis 1 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 1	9	10	Axis 1 Forward Limit Switch
Axis 1 $\overline{\text{Inhibit}}$	11	12	Axis 1 Reverse Limit Switch
Analog Output Ground	13	14	Analog Output 2
Digital Ground	15	16	Axis 2 Encoder Phase A
Digital Ground	17	18	Axis 2 Encoder Phase B
Axis 2 Home Switch	19	20	Axis 2 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 2	21	22	Axis 2 Forward Limit Switch
Axis 2 $\overline{\text{Inhibit}}$	23	24	Axis 2 Reverse Limit Switch
Analog Output Ground	25	26	Analog Output 3
Digital Ground	27	28	Axis 3 Encoder Phase A
Digital Ground	29	30	Axis 3 Encoder Phase B
Axis 3 Home Switch	31	32	Axis 3 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 3	33	34	Axis 3 Forward Limit Switch
Axis 3 $\overline{\text{Inhibit}}$	35	36	Axis 3 Reverse Limit Switch
Analog Output Ground	37	38	Analog Output 4
Digital Ground	39	40	Axis 4 Encoder Phase A
Digital Ground	41	42	Axis 4 Encoder Phase B
Axis 4 Home Switch	43	44	Axis 4 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 4	45	46	Axis 4 Forward Limit Switch
Axis 4 $\overline{\text{Inhibit}}$	47	48	Axis 4 Reverse Limit Switch
Digital Ground	49	50	Host +5 V

Figure B-3. 50-Pin Servo Connector Pin Assignment (Axes 1–4)

Analog Output Ground	1	2	Analog Output 5
Digital Ground	3	4	Axis 5 Encoder Phase A
Digital Ground	5	6	Axis 5 Encoder Phase B
Axis 5 Home Switch	7	8	Axis 5 Encoder Index
Trigger/Breakpoint 5	9	10	Axis 5 Forward Limit Switch
Axis 5 Inhibit	11	12	Axis 5 Reverse Limit Switch
Analog Output Ground	13	14	Analog Output 6
Digital Ground	15	16	Axis 6 Encoder Phase A
Digital Ground	17	18	Axis 6 Encoder Phase B
Axis 6 Home Switch	19	20	Axis 6 Encoder Index
Trigger/Breakpoint 6	21	22	Axis 6 Forward Limit Switch
Axis 6 Inhibit	23	24	Axis 6 Reverse Limit Switch
Analog Output Ground	25	26	Analog Output 7
Digital Ground	27	28	Axis 7 Encoder Phase A
Digital Ground	29	30	Axis 7 Encoder Phase B
Axis 7 Home Switch	31	32	Axis 7 Encoder Index
Trigger/Breakpoint 7	33	34	Axis 7 Forward Limit Switch
Axis 7 Inhibit	35	36	Axis 7 Reverse Limit Switch
Analog Output Ground	37	38	Analog Output 8
Digital Ground	39	40	Axis 8 Encoder Phase A
Digital Ground	41	42	Axis 8 Encoder Phase B
Axis 8 Home Switch	43	44	Axis 8 Encoder Index
Trigger/Breakpoint 8	45	46	Axis 8 Forward Limit Switch
Axis 8 Inhibit	47	48	Axis 8 Reverse Limit Switch
Digital Ground	49	50	Host +5 V

Figure B-4. 50-Pin Servo Connector Pin Assignment (Axes 5–8)

C

Input/Output Reset States

This appendix lists the various states of the NI PXI/PCI-7350 hardware during reset.

Table C-1. I/O States During Reset

Signal Names	Direction	From Power On Until Device Initialization		
		Mode	Polarity	State
Motion I/O Connector				
Inhibit <1..8>	Output	Open collector	Active low	Active
Breakpoint <1..8>	Output	Totem Pole	Active low	Inactive
Step <1..8>	Output	Totem Pole	Active low	Inactive
Direction <1..8>	Output	Totem Pole	Active low	Inactive
Digital I/O Connector				
Digital I/O Ports <1..8>	Input	—	Active low	Pulled up if DPull left floating

D

Technical Support and Professional Services

Visit the following sections of the National Instruments Web site at ni.com for technical support and professional services:

- **Support**—Online technical support resources at ni.com/support include the following:
  - **Self-Help Resources**—For answers and solutions, visit the award-winning National Instruments Web site for software drivers and updates, a searchable KnowledgeBase, product manuals, step-by-step troubleshooting wizards, thousands of example programs, tutorials, application notes, instrument drivers, and so on.
  - **Free Technical Support**—All registered users receive free Basic Service, which includes access to hundreds of Application Engineers worldwide in the NI Developer Exchange at ni.com/exchange. National Instruments Application Engineers make sure every question receives an answer.

    For information about other technical support options in your area, visit ni.com/services or contact your local office at ni.com/contact.
- **Training and Certification**—Visit ni.com/training for self-paced training, eLearning virtual classrooms, interactive CDs, and Certification program information. You also can register for instructor-led, hands-on courses at locations around the world.
- **System Integration**—If you have time constraints, limited in-house technical resources, or other project challenges, National Instruments Alliance Partner members can help. To learn more, call your local NI office or visit ni.com/alliance.
- **Declaration of Conformity (DoC)**—A DoC is our claim of compliance with the Council of the European Communities using the manufacturer's declaration of conformity. This system affords the user protection for electronic compatibility (EMC) and product safety. You can obtain the DoC for your product by visiting ni.com/certification.

- **Calibration Certificate**—If your product supports calibration, you can obtain the calibration certificate for your product at `ni.com/calibration`.

If you searched `ni.com` and could not find the answers you need, contact your local office or NI corporate headquarters. Phone numbers for our worldwide offices are listed at the front of this manual. You also can visit the Worldwide Offices section of `ni.com/niglobal` to access the branch office Web sites, which provide up-to-date contact information, support phone numbers, email addresses, and current events.

Glossary

A

absolute mode	A move mode that treats the target position loaded as position relative to zero (0) while making a move.
absolute position	Position relative to zero.
acceleration/ deceleration	A measurement of the change in velocity as a function of time. Acceleration and deceleration describes the period when velocity is changing from one value to another.
active high	A signal is active when its value is high (1).
active low	A signal is active when its value is low (0).
ADC	analog-to-digital converter
address	Character code that identifies a specific location (or series of locations) in memory or on a host PC bus system.
amplifier	The device that delivers power to operate the motor in response to low-level control signals. In general, the amplifier is designed to operate with a particular motor type. For example, you cannot use a stepper drive to operate a DC brush motor.
Analog Input <1..8>	16-bit analog ADC input.
Analog Output <1..8>	DAC voltage output.
API	application programming interface
axis	Unit that controls a motor or any similar motion or control device.
Axis <1..8> Dir (CCW)	Axis 1 through 8 direction output or counterclockwise direction control.
Axis <1..8> Forward Limit Input	Axis 1 through 8 forward limit switch.
Axis <1..8> Home Input	Axis 1 through 8 home input.

Axis <1..8> $\overline{\text{Inhibit}}$	Axis 1 through 8 inhibit output.
Axis <1..8> Reverse Limit Input	Axis 1 through 8 reverse limit input.
Axis <1..8> Step (CW)	Axis 1 through 8 stepper pulse output or clockwise direction control.

B

b	bit—One binary digit, either 0 or 1.
base address	Memory address that serves as the starting address for programmable or I/O bus registers. All other addresses are located by adding to the base address.
binary	A number system with a base of 2.
bit	The smallest unit of memory, or the smallest unit of data used in a digital operation; a contraction of binary and digit. A bit can assume values of 0 to 1 (off or on).
buffer	Temporary storage for acquired or generated data (software).
bus	The group of conductors that interconnect individual circuitry in a computer. Typically, a bus is the expansion vehicle to which I/O or other devices are connected.

C

CCW	counterclockwise—Implies direction of motor rotation.
closed-loop	A motion system that uses a feedback device to provide position and velocity data for status reporting and accurately controlling position and velocity.
common	Reference signal for digital I/O.
CPU	central processing unit
crosstalk	An unwanted signal on one channel due to an input on a different channel.
CSR	communications status register
CW	clockwise—Implies direction of motor rotation.

D

DAC	digital-to-analog converter
DAQ	data acquisition
dedicated	Assigned to a particular function.
DGND	Digital ground signal.
digital I/O port	Group of digital input/output signals.
DIP	dual inline package
DLL	dynamic link library—Provides the API for the motion control boards.
drive	Electronic signal amplifier that converts motor control command signals into higher-voltage signals suitable for driving motors.
DSP	digital signal processor

E

encoder	A device that translates mechanical motion into electrical signals; used for monitoring position or velocity in a closed-loop system.
encoder resolution	The number of encoder lines between consecutive encoder indexes (marker or Z-bit). If the encoder does not have an index output, the encoder resolution can be referred to as lines per revolution.

F

F	farad
FIFO	first-in, first-out
filter parameters	Indicates the control loop parameter gains (PID gains) for a given axis.
filtering	A type of signal conditioning that filters unwanted signals from the signal being measured.
flash ROM	Type of electrically reprogrammable read-only memory.

following error trip point — The difference between the instantaneous commanded trajectory position and the feedback position. If the following error increases beyond the maximum allowable value entered—referred to as the following error trip point—the motor trips on following error and is killed, preventing the axis from running away.

FPGA — field programmable gate array

freewheel — Condition of a motor when power is de-energized and the motor shaft is free to turn with only frictional forces to impede it.

full-step — A stepper motor mode. For a two phase motor, full-step mode is done by energizing both windings or phases simultaneously.

G

Gnd/GND — ground

H

half-step — A stepper motor mode. For a two phase motor, half-step mode is done by alternately energizing two windings and then only one. In half step mode, alternate steps are strong and weak but there is significant improvement in low-speed smoothness over the full-step mode.

hex — hexadecimal

home switch (input) — A physical position determined by the mechanical system or designer as the reference location for system initialization. Frequently, the home position is also regarded as the zero position in an absolute position frame of reference.

host computer — The computer the motion control board is plugged into.

I

index — The marker between consecutive encoder revolutions.

IRQ — interrupt request—A signal from a hardware device or a CPU peripheral device requesting the CPU's attention.

K

k	kilo—The standard metric prefix for 1,000, or 10^3, used with units of measure such as volts, hertz, and meters.
K	kilo—The prefix for 1,024, or 2^{10}, used with byte (B) in quantifying data or computer memory.

L

LIFO	last-in, first-out
limit switch/ end-of-travel position (input)	Sensors that alert the control electronics that the physical end of travel is being approached and that the motion should stop.

M

MCS	move complete status—A status bit on the motion controller that indicates that the current move is finished. The status depends on various factors that you can configure using software.
microstep	Proportional control of energy in the coils of a stepper motor that allow the motor to move to or stop at locations other than the fixed magnetic/mechanical pole positions determined by the motor specifications. This capability facilitates the subdivision of full mechanical steps on a stepper motor into finer microstep locations that greatly smooth motor running operation and increase the resolution or number of discrete positions that a stepper motor can attain in each revolution.
modulo position	Treat the position as if it is within the range of total quadrature counts per revolution for an axis.

N

noise	An undesirable electrical signal—noise comes from external sources such as the AC power line, motors, generators, transformers, fluorescent lights, soldering irons, CRT displays, computers, electrical storms, welders, radio transmitters, and internal sources such as semiconductors, resistors, and capacitors. Noise corrupts signals you are trying to send or receive.

O

open collector	A method of output capable of sinking current, but not sourcing current.
open-loop	A motion control system where no external sensors (feedback devices) are used to provide position or velocity correction signals.

P

PCI	peripheral component interconnect—A high-performance expansion bus architecture originally developed by Intel to replace ISA and EISA. PCI is achieving widespread acceptance as a standard for PCs and workstations; it offers a theoretical maximum transfer rate of 132 MB/s.
PID control loop	proportional-integral-derivative control loop—A control method in which the controller output is proportional to the error, the error time history, and the rate at which the error is changing. The error is the difference between the observed and the commanded values of a variable that is under control action.
PIVff control loop	proportional-integral-velocity feed forward control loop—A control method that operates with zero derivative gain and either velocity feedback or a velocity block amplifier.
port	(1) A communications connection on a computer or a remote controller; (2) A digital port, consisting of eight lines of digital input and/or output.
position breakpoint	Position breakpoint for an encoder can be set in absolute or relative quadrature counts. When the encoder reaches a position breakpoint, the associated breakpoint (position compare) output immediately transitions.
power cycling	Turning the host computer off and then back on, which causes a reset of the motion control board.
PWM	pulse width modulation—A method of controlling the average current in a motor phase winding by varying the on-time (duty cycle) of transistor switches.
PXI	PCI eXtensions for Instrumentation—A rugged, open system for modular instrumentation based on CompactPCI, with special mechanical, electrical, and software features. The PXIbus standard was originally developed by National Instruments in 1997, and is now managed by the PXIbus Systems Alliance.

Q

quadrature counts	Encoder line resolution multiplied by four.

R

relative breakpoint (position compare)	Sets the position breakpoint for an encoder in relative quadrature counts.
relative position	Destination or target position for motion specified with respect to the current location regardless of its value.
relative position mode	Treat the target position loaded as position relative to current position while making a move.
ribbon cable	A flat cable in which the conductors are side by side.
RPM	revolutions per minute—Units for velocity.
RPSPS or RPS/S	revolutions per second squared—Units for acceleration and deceleration.
RTR	ready to receive—A status bit on the controller indicating that the controller is ready to communicate with the host system.

S

servo	Specifies an axis that controls a servo motor.
s-curve profile	An s-curve acceleration/deceleration profile eases to a start and smoothly accelerates to top speed. Deceleration is equally smooth.
sinusoidal commutation	A method of controlling current in the windings of a brushless servo motor by using the pattern of a sine wave to shape the smooth delivery of current to three motor inputs, each 120° out of phase from the next.
stepper	Specifies an axis that controls a stepper motor.

T

toggle	Changing state from high to low, back to high, and so on.
torque	A force tending to produce rotation.

Totem Pole	A method of output capable of sinking and sourcing current.
trapezoidal profile	A typical motion trajectory, where a motor accelerates up to the programmed velocity using the programmed acceleration, traverses at the programmed velocity, then decelerates at the programmed acceleration to the target position.
trigger (position capture)	Any event that causes or starts some form of data capture.

V

V_{CC}	Positive voltage supply.
velocity mode	This operation mode moves the axis continuously at a specified velocity.

W

watchdog	Timer task that shuts down (resets) the motion control board if any serious error occurs.
word	Standard number of bits that a processor or memory manipulates at one time, typically 8-bit, 16-bit, or 32-bit.

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Symbols

+5 V signal. *See* Host +5 V signal

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